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THE BIOSTATISTICS OF SENILITY

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THE decay of vitality with age is a biological fact most recognize in themselves and none fail to recognize in others; but the biometry of the subject is a difficult undertaking. There is indeed an immense literature, ranging from the moral and psychological observations of Cicero which, of course, edified us in school days to actuarial discussions on the graduation of rates of mortality at advanced ages. To a writer with a predilection for arithmetic the last named studies are more attractive than even Cicero, but he soon discovers that the actuarial treatment of mortality at advanced ages is a matter of art rather than science; partly because the data are either scanty or unreliable, partly because the financial interest of the subject is negligible. In a recent paper Huber has summarized the almost bewildering variety of expedients adopted by official statisticians in different countries to bring life tables to a more or less reasonable end.

To the biostatistician who uses arithmetic, or even algebra, as a tool and not an end in itself, the biological basis of senescence must always be a primary object of curiosity. One does not reach biological truth merely by doing sums. Doing sums, however, is one of the best ways of differentiating biological truth from error.

Fifteen years ago, Raymond Pearl in a course of lectures on the Biology of Death gave a critical survey of relevant biological literature. One conclusion he reached was that, until more accurate observations

had been assembled, theorizing was only an agreeable intellectual amusement. He and his colleagues settled down to the exact comparison of mortality rates in different biological types and, Pearl and Miner (1935) published what, in our opinion, is the best contribution yet made to the subject. We will quote a concluding paragraph. "In the meantime it seems to us that the crying need is for more observational data, carefully and critically collected for different species of animals and plants, that will follow through the life history from birth to death of each individual in a cohort of statistically respectable magnitude. From such data sound and biologically meaningful life tables can be constructed. Work of this character, laborious as it is, is likely to be more fruitful of real knowledge than the construction of any mathematical 'law' of mortality, however ingenious." (Pearl and Miner, *op. cit.* 1935).

This finding confirms the conclusion one of us had drawn in 1928 from much less extensive data, and we have no doubt that the plan proposed is the right strategy. But experience of experimental epidemiology, which is virtually an application of identical scientific principles to the study of disease as a biological mass phenomenon, leads us to believe that few have Charles Darwin's iron self-control and can refrain from speculation in advance of data.

Recently Dr. E. J. Gumbel published a monograph (1937), *La durée extrême de la vie humaine*, which, for several reasons, merits study. As is well known, Gumbel has made important contributions to the study of the sampling-frequency distribution of the greatest or least values of a population, a problem first raised by Francis Galton which other mathematicians, notably Fisher and Tippett (1928), have investigated. Gumbel applied his methods to the particular case of survivorship and in the course of his work reached a result which he termed the paradox of the greatest age. We propose first of all to resume briefly the mathematical argument. Gumbel uses the following notation:—

$l(x) = \int_x^\infty \theta(x)\,dx$ where $\theta(x)$ is the probability that a new-born child will die between the ages x and $x + dx$. ξ is the value of x for which $\theta(x)$ is a maximum, and termed the normal age. $\mathbf{e}(x)$ is the expectation of life at age x.

The probability, $W_N(x)$ that the oldest of N decedents is not greater than x is $W_N(x) = \big(1 - l(x)\big)^N$
and the density of probability $w_N(x)$ is

$$w_N(x) = N\big(1 - l(x)\big)^{N-1}\theta(x) \qquad (1)$$

The modal age of (1) is denoted by $\tilde{\omega}$ and

$$t = \frac{x - \xi}{\mathrm{e}\ (\xi)}\ ,\ \tau = \frac{\tilde{\omega} - \xi}{\mathrm{e}\ (\xi)}$$

Now suppose we have two life tables for which $\xi_1 > \xi_2$ but $\mathrm{e}_1\ (\xi_1) < \mathrm{e}_2\ (\xi_2)$

Then Gumbel reaches the conclusion that

$$\tilde{\omega}_1 \begin{matrix} < \\ = \\ > \end{matrix} \tilde{\omega}_2 \tag{2}$$

if

$$\tau \begin{matrix} > \\ = \\ < \end{matrix} (\xi_1 - \xi_2) \Big/ \left\{ \mathrm{e}_2\ (\xi_2) - \mathrm{e}_1\ (\xi_1) \right\} \tag{3}$$

so that for the more favorable table (i.e. the table for which the normal age is older) the most probable value of the "oldest age" of a sufficiently large group[1] is less than in the unfavorable table. For instance the normal age of white males 1901 U. S. A. experience was 75.05 years, of colored males 56.92 years. The "oldest ages" deduced by Gumbel were 113 and 121 years. The corresponding observed values were 119 and 128 years.

We shall summarize the mathematical argument. Differentiating (1) to obtain a maximum we have

$$\frac{N - 1}{1 - l\ (\tilde{\omega})}\ \theta\ (\tilde{\omega}) + \frac{\theta'(\tilde{\omega})}{\theta\ (\tilde{\omega})} = 0 \tag{4}$$

A first approximation is reached by assuming N large in comparison with unity and unity large in comparison with $l\ (\tilde{\omega})$, so approximately

$$N = -\frac{\theta'(\tilde{\omega})}{\theta^2(\tilde{\omega})} \tag{5}$$

Now suppose that the force of mortality at the oldest age may be represented by:—

$$\mu\ (\tilde{\omega}) = -\frac{\theta'(\tilde{\omega})}{\theta\ (\tilde{\omega})} \tag{6}$$

it follows that

$$l\ (\tilde{\omega}) = \frac{1}{N} \tag{7}$$

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[1] This quantity is called by Gumbel the *"dernier age"*. We translate this "oldest age", the inverted commas indicating the technical use of the expression.

If this holds it may be shown that

$$\tilde{\omega} = \xi + \mathrm{e}\,(\xi)\ \mathrm{F}\ [\log N\, l\,(\xi)] \qquad (8)$$

which implies that for $x \geqq \xi$

$$l\,(x) = l\,(\xi)\ \exp\left[-f\left(\frac{x-\xi}{\mathrm{e}\,(\xi)}\right)\right]$$

where $f\left(\frac{x-\xi}{\mathrm{e}\,(\xi)}\right)$ is a steadily increasing function of x with at least two differential coefficients, and F is the inverse function of f. Equation (5) is clearly reasonable. With respect to (6) we note that, by definition,

$$\mu\,(x) = -\frac{l'(x)}{l\,(x)}$$

and that

$$\lim_{x\to\infty} \frac{l'(x)}{l\,(x)} = -\lim_{x\to\infty} \frac{\theta\,(x)}{l\,(x)} = \lim_{x\to\infty} \frac{\theta'(x)}{\theta\,(x)}$$

If the limiting values of $\theta'(x)$ and $\theta\,(x)$ were both finite and not zero, (6) would be ultimately exact and (7) must hold. But the limits of both $\theta'(x)$ and $\theta\,(x)$ as x tends to infinity are zero.

But it is true that

$$\lim_{x\to\infty} \frac{\mu\,(\tilde{\omega})}{\theta'(\tilde{\omega})/\theta\,(\tilde{\omega})} = 1$$

Also (5) holds and

$$N = \frac{1}{l\,(\tilde{\omega})}\left(1 - \frac{\mu'(\tilde{\omega})}{\mu^2(\tilde{\omega})}\right) \qquad (9)$$

follows from the definition of $\mu\,(x)$ and the relation:—

$$\theta'(x) = l\,(x)\ \ (\mu'(x) - \mu^2(x))$$

We think it is difficult to conceive a 'law' of mortality such that $\frac{\mu'(x)}{\mu^2(x)}$ will not tend to zero as x tends to infinity. Hence, we think, Gumbel's argument is sound and that the 'paradoxical' result stated above follows. We may illustrate the result easily on so simple a 'law' as that of Gompertz. Here $l\,(x) = k\,g^{c^x}$ where c is greater and g less than unity. It may easily be shown (see Gumbel 1937, p. 15) that the force of mortality at the normal age is equal to the natural logarithm of c. Now suppose we have two tables both following Gompertz's law from any

age we please in relatively early life. Take, for instance, The Manchester Township Life Table (Males) 1881-90 and English Life Table No. 10 (Males). The former is a very unfavorable, the latter a very favorable table. For the former the normal age is between 50 and 51 and the expectation of life at that age between 12.8 and 12.4 years. For the latter the normal age is between 74 and 75 and the expectation of life at that age about 6.8 years. Now the force of mortality at 74 by English Life Table No. 10 is greater than the force of mortality at 50 by the Manchester Township Table (the approximate values are 0.0865 and 0.0477). If, therefore, both tables followed Gompertz's law, the relations being:—

For English Life Table No. 10 ${}_1l\ (x) = k_1\, g_1{}^{c_1^x}$

For Manchester Township Table ${}_2l\ (x) = k_2\, g_2{}^{c_2^x}$

it is clear that $c_1 > c_2$

If we suppose Gompertz's law to apply exactly to both tables from, say, age 60, then as from 100,000 entrants, the survivors at 60 are respectively 63,620 and 14,945, or ${}_1l\ (o) > {}_2l\ (o)$. Therefore $k_1\, g_1 > k_2\, g_2$

Write $$\left\{ {}_1l\ (x) \,/\, {}_2l\ (x) \right\} = r_x$$

Then

$$\log r_x = \log k_1 - \log k_2 + c_1{}^x \log g_1 - c_2{}^x \log g_2 \qquad (10)$$

Putting $x = 0$, $\log r_0 > 0$ because $k_1\, g_1 > k_2\, g_2$

But; since $c_1 > c_2 > 1$ and both $\log g_1$ and $\log g_2$ are negative, we can by increasing x sufficiently make $\log r_x$ negative.

Hence the table giving the large proportion of survivors at a relatively early age must give the smaller proportion at some very advanced age and conversely. This illustrates Gumbel's reasoning.

The whole argument, of course, depends on the assumption that the two populations, or tables, follow the same law — whatever the law may be. That it is not necessarily true that ultimate survivorship will be less favorable under a good than under a bad table may easily be shown. Pearl (1928) published life tables for two genetically distinct races of *Drosophila*, the long-lived wild type and the short-lived vestigial type. Line 107 of the former (males) had a normal age of 51 days (approximately) and an expectation of life at that age of 10 days. Vestigial males had a normal age of 11 days and a normal expectation of 7.9

days. A straight comparison will create no paradox for the normal expectation of the vestigial flies is less than that of the wild flies. But we can easily choose a mixture of the two such that, for the mixture, the expectation of life at the (younger) normal age for the mixture will be greater than the expectation of life at 51 days for the wild flies. If, for instance, we form a life table by taking 1/10th of the l_x for wild flies and 9/10ths for the l_x for vestigial flies, the normal age will still be approximately 11 days but the expectation of life at that age will be 10.76 days as against 10 days in the wild type. But biologically speaking the presence of the short-lived flies is irrelevant; ultimate survivorship depends wholly upon the wild line. This does not, of course, impugn in any way Gumbel's reasoning; *ex hypothesi,* the 'law' of mortality in the mixture could not in general be of the same form as that of the wild type.

This may be shown as follows. Let us assume that the laws of mortality were the same for the wild type and the mixture, and of the general form postulated by Gumbel. Then we have:—

Wild type
$$l_1(x) = l_1(\xi_1) \exp\left[-f\left(\frac{x-\xi_1}{\mathbf{e}(\xi_1)}\right)\right] \qquad (11)$$

Mixture
$$l_2(x) = l_2(\xi_2) \exp\left[-f\left(\frac{x-\xi_2}{\mathbf{e}(\xi_2)}\right)\right] \qquad (12)$$

Here
$$\xi_1 = 51, \mathbf{e}(\xi_1) = 10, \xi_2 = 11, \mathbf{e}(\xi_2) = 10.76$$

thus
$$\xi_1 > \xi_2 \text{ and } \mathbf{e}(\xi_1) < \mathbf{e}(\xi_2)$$

Since ultimate survivorship depends wholly upon the wild line we must assume that
$$\left\{l_2(x) / l_1(x)\right\} \to 0.1 \text{ as } x \to \infty .$$

Let
$$x = \xi_1 + a = \xi_2 + (a + \xi_1 - \xi_2)$$

then
$$l_1(x) = l_1(\xi_1) \exp\left[-f\left(\frac{a}{\mathbf{e}(\xi_1)}\right)\right]$$
$$l_2(x) = l_2(\xi_2) \exp\left[-f\left(\frac{\xi_1 - \xi_2 + a}{\mathbf{e}(\xi_2)}\right)\right]$$

Hence

$$\log l_2(x) - \log l_1(x) =$$
$$\log l_2(\xi_2) - \log l_1(\xi_1) + f\left(\frac{a}{\mathbf{e}(\xi_1)}\right) - f\left(\frac{\xi_1 - \xi_2 + a}{\mathbf{e}(\xi_2)}\right) \quad (13)$$

Now ultimately $\xi_1 - \xi_2$ and $\log l_1(\xi_1) - \log l_2(\xi_2)$ are both very small compared with a, and since $\mathbf{e}(\xi_2) > \mathbf{e}(\xi_1)$ the right hand side of this expression will ultimately become positive and large. For instance with Lexis' hypothesis $f(u) \sim \left(\frac{u^2}{\pi} + \log 2u\right)$ and

$$\log l_2(x) - \log l_1(x) = \frac{a^2}{\pi}\left[\frac{1}{\mathbf{e}^2(\xi_1)} - \frac{1}{\mathbf{e}^2(\xi_2)}\right] \text{ approximately,}$$

that is the ratio of $l_2(x)$ to $l_1(x)$ becomes very large. But this contradicts the hypothesis that $[l_2(x) / l_1(x)] \to 0.1$. Hence the form of the function f cannot be the same in both cases.

We are now brought to an important and highly relevant consideration. It has long been suspected that a genetic factor of longevity exists; the work of Pearl and his collaborators has greatly strengthened the case for believing that capacity to live long is heritable. If this be true it follows that with advancing age the quality of the population changes, in fact the analogy between a mixture of wild and vestigial flies and the human population may be an exact analogy.

If we further suppose that, under an unfavorable environment, the wild flies are more resistant to the factors causing death before old age has begun, we could understand how, in a 'bad' table, rates of mortality at relative advanced ages might be more favorable than in a 'good' table. But it is not easy to understand how the age attained on the average by one in a vast number of entrants to life would be affected, provided that the initial proportion of wild flies in the population is the same under the two environments. We are, therefore, led to consider whether there is any good reason to believe that a uniform law of mortality does apply to the facts of human experience. The merits and demerits of the Gompertz or Makeham-Gompertz formulae have been discussed many times (see e.g. Greenwood, 1928). Gumbel has given attention to Lexis' system, which has also been warmly praised by Freudenberg. This is less familiar than the Makeham-Gompertz or Gompertz formulae and we shall describe it in some detail.

Lexis's theory of mortality was first published in 1877 (Lexis, 1877 pp. 42 *et seq.*) and again stated with little change in 1903 (see Lexis,

1903 pp. 111 *et seq.*). He, following to some extent Quetelet but, with a nuance of Platonism, thought of a typical or normal age of man to the attainment of which the nature of things was striving. Were there no disturbing factors, the life table distribution of deaths in a generation would be a normal curve, the origin of which would be the normal age. But in real life there would be disturbing factors. In the first place some of those born would be constitutionally unfit for long survival; in the second place unfavorable environmental factors would lead to the premature death of some fitted to reach the normal age. Lexis illustrated his theory by an analogy. He imagined the case of a man throwing balls at a mark who, if undisturbed, would distribute these balls on either side of the mark in a Gaussian distribution, but who was actually disturbed in two ways. Firstly, some of the balls he picked up seemed too light or too heavy; these he dropped at his feet. Secondly a mischievous person ran along the skittle alley, put out his hand, caught and dropped some of the balls in flight, confining his attention to the nearer side of the alley, and not interfering with over-pitched balls. Under these conditions the over-pitched balls will be distributed in a Gaussian way so that one will have from the normal age the half of a normal curve, while, prior to that age, the distribution would have an early maximum and then approach slowly to the value at the normal age. Lexis tested this hypothesis on a large number of life tables. His method was, starting with the tabular values of d_x to fix the normal age (i.e. the age for which d_x was maximal) and then, usually on a range of about 8 years, to deduce the value of the standard deviation. E.g. if the normal age were 72, the number of deaths between 72 and 80 were 100, and the whole number of deaths beyond 72 were 200, one would enter Sheppard's table for $\frac{1}{2}(1 + \alpha) = 0.75$ obtain the value of $8/\sigma$ and so deduce σ. On many tables the agreement between observation and expectation seemed to Lexis satisfactory.

It may be urged that the statistical method is rather crude and that in fact no precise test of agreement between observation and theory was applied. Lexis, however, belonged to an order of intelligence much above the level at which schoolmasterly criticisms are appropriate. So far as the question of method is concerned, he did not need to be told that an arithmetically better fit might easily be obtained for a given set of data by using more of the data. He only used a small range because he knew that the further one went in a published life table the more sophisticated by interpolation, graduation, etc., were the values printed

in it and he wished to base his argument on a range over which the data were least doctored.

So far as the question of fit is concerned, he was quite aware that so simple a law as he proposed could hardly account for the whole of the facts, and was, therefore, content to reach approximate results. Freudenberg (1934), using a more refined process of deducing the standard deviation and working with more modern data also reached apparently good concordance of d_x's beyond the normal age with those required by the hypothesis of Lexis. But to say this is not to say that the hypothesis of Lexis is free from difficulty. In the first place it is to be noted that the normal age in Lexis's sense has moved further on in life. In the terms of Lexis's parable, the skittle player has fixed his eye on a mark further down the alley. Freudenberg (*op. cit.*, p. 383) using German Life Tables from 1871-1881 to 1924-1926 has an increase from 70.1 years to 75.4 years for males (σ decreased from 9.53 to 8.12) and from 72.2 to 76.2 years for females (σ decreased from 8.30 to 8.20).

We have used four tables based on English experience, viz. E. L. 7 and 10 and the 'ultimate' tables based on annuitant experience by Elderton and Oakley (1924). In the national tables the range of normal ages is much smaller (as one would expect) but while for E. L. 7 (the mortality rates prevailing 30 years ago) the normal age is 79.8 years it is 85.5 years for the very select annuitants. It is at least clear that our hypothetical skittle player shifts his mark. This is rather difficult to reconcile with the original hypothesis. The argument was that, ideally, we should have a normal frequency distribution of the variate d_x and that practically we did *not* have such a distribution, partly because the data themselves were distorted by manipulation but partly — and in greater part — by the intrusion of deaths, the juvenile and premature deaths, which were strictly speaking accidental impurities. With the reduction of these by environmental betterment the pure idea should emerge more distinctly. But the normal age could hardly move unless we suppose that the mark is changed. If, owing to hygienic betterment or selection, the *quality* of young lives is improved — in terms of the analogy the box of balls used by the thrower contains fewer too light or too heavy balls — one would perhaps expect the scatter to diminish, but hardly the position of the target.

In spite of our respect for Lexis as a statistician, we cannot discern in his treatment of the mortality table any biological superiority to that of, for instance, Karl Pearson, who dissected the table into a series of

components, a method adopted in principle by Arne Fisher. The Lexian method has an advantage over the Pearsonian method in so far as fewer constants are needed (see Pearl, 1922, pp. 94-100) but not, so far as appears, any intrinsic merit. The analogy of the skittle player is only an analogy, without biological justification.

Possibly such relative advantage over the method of Gompertz as Freudenberg found means no more than that the rate of mortality increases with age more slowly than the 'law' of Gompertz requires. Gumbel has pointed out that it must follow algebraically that when the

TABLE 1

English Life Table No. 10 (*Females*)

AGE	'OBSERVED' d_x	CALCULATED (LEXIAN METHOD)
80	2949	2860.5
81	2834	2795.9
82	2684	2709.4
83	2505	2550.7
84	2303	2333.6
85	2080	2116.8
86	1843	1864.9
87	1599	1597.0
88	1347	1355.9
89	1114	1117.9
90	905	896.1
91	720	712.2
92	561	549.5
93	426.9	412.3
94	316.9	306.7
95	229.0	221.4
96	160.8	156.4
97	109.5	107.4
98	72.2	73.2
99	45.9	48.4
100	28.1	31.1
101	16.6	19.8
102	9.3	12.3
103	5.0	7.4
104	2.6	4.4
105	1.2	2.8
106	0.6	3.1

TABLE 2

Graduations of various tables by Gompertz's method (G) and Lexis's method (L). Tabular values (d_x's) expressed as percentages of the graduated values

AGE	MANCHESTER CITY 1881-90		MANCHESTER CITY 1881-90		E.L. NO. 7		E.L. NO. 7		E.L. NO. 10		E.L. NO. 10	
	M.G.	M.L.	F.G.	F.L.	M.G.	M.L.	F.G.	F.L.	M.G.	M.L.	F.G.	F.L.
80	94.2	102.4	90.7	101.2	82.8	105.3	80.9	104.1	91.2	102.8	87.4	103.1
81	96.1	100.0	93.2	100.5	85.0	100.6	84.0	100.6	93.7	100.7	90.4	101.4
82	96.9	99.0	95.6	99.9	87.7	97.2	87.2	99.0	95.9	98.6	93.2	99.1
83	98.7	98.2	97.4	99.4	91.0	96.7	90.7	97.4	97.8	98.5	95.8	98.2
84	99.9	98.6	98.9	99.0	94.7	96.3	94.4	97.5	99.4	98.3	98.2	98.7
85	100.7	97.8	101.0	99.6	98.4	97.9	98.0	98.2	100.8	98.5	100.2	98.3
86	101.2	98.6	101.2	98.9	101.7	99.2	101.1	99.7	101.7	98.4	101.8	98.8
87	101.3	98.1	101.3	98.3	104.4	100.0	103.3	99.8	102.2	99.7	102.7	100.1
88	101.6	99.4	102.7	99.4	106.7	102.3	105.0	100.6	101.7	99.9	102.4	99.3
89	102.6	100.6	102.4	99.2	108.7	103.6	106.1	101.5	101.2	100.3	101.9	99.6
90	103.4	102.7	103.6	100.5	109.5	105.6	106.5	102.3	100.8	100.3	101.6	101.0
91	99.5	99.0	100.7	98.7	108.8	105.5	106.2	103.2	100.5	102.0	101.2	101.1
92	102.2	102.9	101.5	99.7	106.1	103.2	105.1	102.2	100.2	102.6	100.8	102.1
93	103.1	106.4	102.4	101.6	102.0	100.7	103.2	101.4	99.8	102.3	100.5	103.5
94	89.6	92.3	99.5	100.0	97.4	96.3	101.1	100.3	99.7	103.0	100.2	103.3
95	111.1	116.3	99.3	100.7	93.3	93.2	98.8	98.8	99.4	102.2	99.9	103.4
96	69.0	69.0	97.1	99.0	89.9	89.6	96.9	98.0	99.5	100.7	99.6	102.8
97	100.0	105.3	94.6	97.2	89.0	87.4	95.6	96.0	99.2	97.3	99.4	102.0
98	83.3	83.3	94.3	100.0	90.3	87.9	94.9	94.8	99.1	94.1	99.2	98.6
99	142.9	142.9	108.1	114.3	93.8	88.0	95.6	94.2	100.0	89.8	98.9	94.8
100	100.0	90.9	80.0	83.3	100.4	90.9	96.9	93.2	100.0	83.3	98.6	90.4
101	....	....	117.6	125.0	109.0	93.4	99.9	93.2	100.0	74.1	99.4	83.8
102	....	....	90.9	90.9	114.5	89.6	100.9	88.9	100.0	67.7	98.9	75.6
103	....	....	142.9	142.9	117.6	84.0	106.6	88.0	100.0	55.6	98.0	67.6
104	....	....	83.3	83.3	97.6	60.6	105.5	79.8	....	....	....	....
105	....	....	....	....	60.1	27.8	105.8	72.4	....	....	....	....

same data are graduated by the two methods, the Lexian values of l_x will first be less and then greater than the corresponding Gompertzian values. At this point some arithmetical illustrations may be helpful. We took first[2] English Life Table No. 10 (females) treated the d_x column for age 80 onwards as the tail of a normal curve and obtained

TABLE 3

Ultimate table of annuitant experience (Elderton and Oakley). Graduations by Gompertz's method (G) and Lexis's method (L). Tabular values (d_x's) expressed as percentages of the graduated values

	M.G.	M.L.	F.G.	F.L.
80	99.9	105.6	....	....
81	100.0	102.4	....	....
82	100.0	98.8	....	....
83	100.0	97.7	....	....
84	100.0	96.0	....	....
85	100.0	96.5	94.0	104.5
86	100.0	96.2	96.2	100.8
87	100.0	97.2	98.0	99.2
88	100.0	99.2	99.4	97.4
89	100.0	100.2	100.3	97.4
90	100.0	102.7	101.0	97.5
91	100.0	103.8	101.3	97.6
92	100.0	106.1	101.3	99.3
93	100.0	106.5	101.1	100.7
94	100.0	107.2	100.7	101.6
95	100.0	107.6	100.2	103.8
96	100.0	105.4	99.7	105.1
97	100.0	103.3	99.2	105.4
98	100.0	98.3	98.7	106.4
99	100.0	92.4	98.5	105.1
100	100.0	85.5	98.5	104.0
101	100.0	75.9	98.9	100.8
102	99.9	66.4	99.8	95.6
103	100.0	55.3	101.3	90.0
...	....	....	....	....

[2] We are much indebted to our colleagues Dr. Martin and Mr. Cheeseman for carrying out this and much more heavy arithmetical work for us.

the constants by Pearson's method.[3] The result (see Table 1) is, from the graphical point of view, excellent. Indeed grouping the values from age 98 onwards together, the fit, on the basis of the life table numbers is excellent, for $\chi^2 = 9.5$. This would, on the tabular numbers, imply an excellent fit. But the actual number of deaths at ages over 80 from which the table as calculated was 111,746 so that one should multiply the value of χ^2 by almost 4.49 for a strict test. Perhaps, however, such comparisons are unreasonable. It would be naive to expect good fits in the sense of the test, because, *inter alia,* one is using as data not the original material but artificially graduated figures. The fairest comparison of Gompertzian with Lexian results would seem to be to show the respective percentage deviations for a wide range of tables. This is done in Table 2. We think the entries lead to the conclusion that neither method has an overwhelming advantage over the other and that neither has any pretention to be regarded as a natural 'law'. Indeed the only table which does give a decisive superiority to one or other method is the Ultimate Table of the Annuitant Experience, Table 3, for which a Gompertzian graduation does completely reproduce the d_x's from age 80; *not* a very strange result as the table was graduated by joining two Gompertz graduations (see Elderton and Oakley, *op. cit.* p. 40)! What *was* a little surprising was that a 'normal' tail did fit the 'facts' quite well over the range 81-90, with a maximum percentage error of 4.0 and only diverged widely after age 98. We conclude (a conclusion long since reached by actuaries) that none of these 'laws' is anything but a useful interpolation formula. Hence, we think, no arithmetical calculation of the 'last age' has much value.

But one has a certain human curiosity regarding the 'true' law of mortality at old ages. Since the data are, statistically speaking, scanty while the practical importance (from the actuarial side) is trivial, the subject had not been discussed in detail, before Gumbel's work. We can only speculate, but a few conjectures may be allowed. Two sets of facts are suggestive. In the first place, as mentioned above, it has long been held that a constitutional factor is of primary importance to the attainment of great length of days; the earlier literature is succinctly discussed by Rolleston (1922, pp. 32 *et seq.*) and more recently Pearl

[3] Fitting by Lexis' original method from the normal age (77 years for this table) gives a rather less good result. For all other fittings the Pearsonian method has been used.

and his collaborators (see Pearl and Raenkham, 1932, *et al.*) have made substantial contributions to the case in favour of an heritable element.

In the next place a study of the actual data of mortality at very advanced ages — say at ages over 90 — produces the impression that the increase of mortality rate with age advances at a slackening rate, that nearly all, perhaps all, methods of graduation of the type of Gompertz's formula *over-state* senile mortality. The weights of these two sets of data are very unequal. We do not have much doubt that the importance of an hereditary factor of longevity is proven, but the comparatively scanty 'facts' — in the actuarial sense — of statistical mortality do not lend themselves to firm conclusions.

From the first and more weighty evidence we may reasonably conclude that the "law" of senile mortality, meaning for the present the functional relation between force of mortality and age could not well be the same for all members of a population. It must be different for the genetically long-lived and the genetically short-lived. It is different for annuitants and insured persons. With our present knowledge the rates of the very aged could never be predicted from an extrapolation of mortality rates based on earlier ages, the exposed to risk are not random samples of an entering population but selections, and extrapolations will consequently exaggerate senile mortality. The much less weighty evidence, or impression, derived from the scanty data of statistical records justify us in speculating on the *possibility* that with advancing age the rate of mortality asymptotes to a finite value. At first sight this must seem a preposterous speculation. In a labile, highly specialized metazoan, decay must surely continue. One cannot without absurdity believe that, other things equal, a man of 100 is not more likely to die within a year than a man of 90. But other things are *not* equal. Swift's gloomy parable of the Struldbrugs is not without its practical application. With advancing years the disabilities, forcefully described by a large number of poets whom it is needless to quote, restrict activities. Even the juvenile of 60, if ordinarily intelligent, eschews the violent exercises of the child of 40. Centenarians rarely appear in public. A statistical rate of mortality might show no increase with age, if the demands made on the vital forces diminished *pari passu* with the decay of vigour.

Let us think then of a group of aged persons who have attained the age of x (where x is greater than 90 years) as competitors for prizes, the prizes being awarded to those who survive 1, 2, etc., years. Who-

ever dies at an age less than $x + 1$ has won no prize, he who dies between $x + 1$ and $x + 2$ has won 1 prize and so forth. Then with a mere change of nomenclature we have the statistical situation considered by Yule and Greenwood in their 1920 paper. If the competitors have equal chances of winning prizes, the graduation of the d_x column should be a simple Poisson series; if their chances are unequal the graduation might follow the simple skew form which was christened the Infinitely Compound Poisson distribution.[4]

The graduation could evidently hold only at extreme ages and involves as a corollary that q_x tends to a finite limit less than unity.

In the form convenient for computation the successive frequencies are given by the terms of :—

$$\left(\frac{c}{c+1}\right)^r \left(1 + \frac{r}{(c+1)} + \frac{r(r+1)}{2!\,(c+1)^2} + \ldots\ldots\ldots\right) \quad (14)$$

where $m = \dfrac{r}{c}$ and $\mu_2 = \dfrac{r(c+1)}{c^2}$

If $c \to \infty$, m remaining finite,

$$\left(\frac{c}{c+1}\right)^{mc} \to e^{-m}$$

and the expression becomes $e^{-m}\left(1 + m + \dfrac{m^2}{2!} + \ldots\ldots\ldots\right)$ the simple Poisson.

The limiting value of q_x is $\left(\dfrac{r}{r+m}\right)$

---

[4] We are aware that this is an over-simplification. If this form of graduation proves satisfactory, it will, we think, lend support to the hypothesis that our populations are heterogeneous with regard to longevity. But the negative binomial cannot be the true law. The form of the distribution to which the hypothesis tends is not strictly independent of the interval of age taken as a unit. If we fit with an interval of one year and then combine our theoretical frequencies for two-year intervals, the new distribution is not a negative binomial in terms of the new interval. Yet a direct fit of a negative binomial to two-year intervals might be good enough for practical purposes of graduation.

There is another point of interest. We show that this hypothesis ultimately leads to a constant q_x and therefore to a constant force of mortality. But this means that ultimately $l(x)$ approaches the exponential form $ae^{-\lambda x}$. The reader may therefore enquire whether Gumbel's "paradox" would not hold for two populations for which our hypothesis was correct. This does not follow, for Gumbel's paradox depends on the form of the function f in $f[(x-\xi)/e(\xi)]$ being the same for both populations *from the normal age onwards.*

Thus

$$\frac{d_x}{l_0} = \left(\frac{r}{r+m}\right)^r \frac{r\,(r+1).....(r+x-1)}{x\,!} \left(\frac{m}{r+m}\right)^x \quad (15)$$

$$\frac{l_x}{l_0} = \left(\frac{r}{r+m}\right)^r \frac{r\,(r+1).....(r+x-1)}{x\,!} \left(\frac{m}{r+m}\right)^x u_x$$

where

$$u_x = 1 + \frac{r+x}{x+1}\left(\frac{m}{r+m}\right) + \frac{(r+x)\,(r+x+1)}{(x+1)\,(x+2)}\left(\frac{m}{r+m}\right)^2 + ... \quad (16)$$

When $x \to \infty$

$$u_x \to 1 + \left(\frac{m}{r+m}\right) + \left(\frac{m}{r+m}\right)^2 + ... = \left(\frac{r+m}{r}\right),$$

or $$q_x \to \left(\frac{r}{r+m}\right)$$

In the simple Poisson

$$d_x = \frac{e^{-\lambda}\,\lambda^x}{x\,!}$$

and by a similar agreement we find

$$q_x \to 1 \text{ as } x \to \infty.$$

In a life table the curtate expectation of life would be the m of this notation.

If this is of order 6 years (its value at the maximum of d_x in E. L. 10) and if the limiting value of q_x for x tending to infinity were of order 0.5, c must be of order unity and r approximately equal to 6. In other words, the d_x's would be still increasing. Hence the graduation could not apply to any system of d_x's for which e_x was greater than 2, i.e. it would not apply to ages less than about 90.

The method is so simple that a trial of its practical applicability seemed justified. A first test was made on the recorded deaths at ages 92 years and upwards in the Annual Reports of the Registrar-General for 1921-35. It is hardly necessary to say that to treat these figures as the d_x's of a life table is to be deliberately guilty of the fault of constructing a life table from the deaths in a non-stationary population. But as a rough preliminary test on large numbers the plan seemed worth trying.

As a matter of arithmetical fact the q_x's of this pseudo life table for males agreed closely with the smoothed values of E. L. 10:—

Age	q_x *of pseudo table*	q_x *of E.L. 10*
92	0.321	0.320
93	0.348	0.338
94	0.368	0.357
95	0.367	0.376
96	0.397	0.396
97	0.393	0.417
98	0.420	0.438
99	0.432	0.461
100	0.453	0.481

TABLE 4

1921-35. Deaths. (Data from R-G's Reports)

AGE	MALES									
	Obs.	Compound Poisson								
92	4348	....	....	....	....	....	.....	.....	.....	4202.6
93	3202	....	....	....	....	....	.....	.....	3100.5	3324.4
94	2204	....	....	....	....	....	.....	2118.6	2280.1	2260.7
95	1389	....	....	....	....	....	1366.1	1501.1	1486.2	1453.7
96	953	....	....	....	....	924.1	963.7	952.8	927.4	907.8
97	568	....	....	....	562.8	610.0	602.8	581.3	565.8	556.9
98	369	....	....	363.6	373.0	367.6	361.0	347.5	340.4	337.5
99	220	....	215.4	224.7	222.3	214.5	211.4	205.2	202.9	202.7
100	131	123.0	130.7	129.2	127.6	123.1	122.1	120.1	120.2	121.0
101	63	75.2	73.9	73.4	71.8	70.0	69.9	69.9	70.8	71.8
102	40	42.1	40.8	40.0	39.9	39.5	39.7	40.5	41.5	42.5
103	30	22.9	22.2	22.0	22.0	22.2	22.5	23.4	24.3	25.0
104	10	12.2	12.0	12.0	12.1	12.4	12.7	13.5	14.2	14.7
105	8	6.5	6.5	6.5	6.6	6.9	7.1	7.7	8.3	8.6
106	5	3.4	3.5	3.5	3.6	3.8	4.0	4.4	4.8	5.0
107	1	1.8	1.8	1.9	1.9	2.1	2.2	2.5	2.8	2.9
108	.	.9	1.0	1.0	1.1	1.2	1.2	1.4	1.6	1.7
109	.	.5	.5	.6	.6	.7	.7	.8	.9	1.0
110	1	.5	.7	.6	.7	.9	.9	1.3	1.3	1.5

TABLE 4 (*Continued*)

1921-35. Deaths. (Data from R-G's Reports)

AGE	FEMALES									
	Obs.	Compound Poisson								
92	10063	....	....	....	.....	.....	.....	.....	.....	9332.9
93	7473	....	....	....	.....	.....	.....	.....	6998.5	8065.4
94	5433	....	....	....	.....	.....	.....	5138.3	5852.8	5852.6
95	3878	....	....	....	.....	.....	3689.2	4146.7	4125.9	3976.6
96	2650	....	....	....	.....	2561.6	2861.9	2834.7	2728.0	2610.1
97	1789	....	....	....	1771.2	1918.3	1893.3	1821.2	1744.0	1677.0
98	1238	....	....	1215.5	1249.4	1229.6	1180.4	1132.6	1092.0	1062.0
99	774	....	740.1	778.5	768.8	743.9	713.5	690.4	674.2	665.5
100	426	405.4	462.1	455.8	450.0	436.6	423.1	415.2	412.0	413.8
101	249	272.3	265.0	258.5	256.6	251.6	247.7	247.2	249.9	255.7
102	153	157.4	147.4	144.2	144.1	143.2	143.6	146.1	150.6	157.2
103	80	86.1	80.8	79.7	80.0	80.7	82.7	85.9	90.4	96.2
104	48	45.8	43.8	43.7	44.1	45.2	47.4	50.2	54.0	58.7
105	37	23.9	23.6	23.9	24.1	25.2	27.0	29.3	32.1	35.7
106	13	12.3	12.7	13.0	13.2	14.0	15.3	17.0	19.1	21.7
107	7	6.3	6.8	7.1	7.2	7.7	8.7	9.8	11.3	13.1
108	2	3.2	3.6	3.8	3.9	4.3	4.9	5.7	6.7	7.9
109	1	3.3	4.1	4.3	4.4	5.1	6.3	7.7	9.5	11.9

TABLE 5

Values of χ^2 for deaths (1921-35) observed and calculated by Compound Poisson. (Last two ages grouped.)

MALES	χ^2	n'	P	FEMALES	χ^2	n'	P
From age 92	30.1422	16	.012	From age 92	214.2177	15	<.000000
" " 93	25.2692	15	.032	" " 93	131.8712	14	<.000000
" " 94	22.5117	14	.048	" " 94	79.8604	13	<.000000
" " 95	9.6850	13	.643	" " 95	49.9437	12	.000003
" " 96	10.7766	12	.463	" " 96	24.1411	11	.0073
" " 97	6.4359	11	.776	" " 97	12.9341	10	.166
" " 98	6.4711	10	.691	" " 98	13.8827	9	.085
" " 99	6.9111	9	.546	" " 99	16.1209	8	.024
" " 100	7.8754	8	.345	" " 100	13.2187	7	.040

In the next table (Table 4) we have the results of graduation by Compound Poissons for various starting ages and in the following table (Table 5) the Tests for Goodness of Fit (three degrees of freedom are absorbed in the fitting). The results for males are surprisingly good; for females, bad from the accurate point of view, although graphically not preposterous.

We were encouraged to seek more exact data. The Report on the Mortality Experience of Government Life Annuitants, 1900-1920 (S. O. 1924), contains data of interest. Actually in the tabular matter one has not lives but contracts so that the life upon which two annuities have been purchased will have two exposures and, of course, two deaths. For reasons stated this is preferable for the purposes of the report, but not for our object. It means, or may mean, that the exposed lives are appreciably less numerous than the exposed contracts, and perhaps goes a little way to explain the violent fluctuations of the observed rates of mortality. Take for instance the relatively large experience of female annuitants exclusive of the first year after purchase. From age 93 onwards one has the following figures:—

	Exposed to risk	*Deaths*	q_x
93	830	276	0.33253
94	550	159	0.28909
95	372	115	0.309139
96	247	73	0.295546
97	177	59	0.333333
98	113	37	0.327433
99	78	29	0.371794
100	47	17	0.361170
101	28	11	0.392857
102	17	2	0.117647
103	15	5	0.333333
104	8	5	0.6250
105	3	3	1.00000

These are distressingly unreasonable figures on *any* hypothesis. To graduate them on so simple a hypothesis as that of the 'proneness' rule is a desperate undertaking. Still courage is sometimes virtuous. We began by taking the figures precisely as they stood. We chose 830 as radix and obtained the successive values of l_x by multiplication by the p_x's, just as they were. One had then 830, 554, 394, 272, 192, 128, 86, 54, 33, 29, 19, 7, 0. So the d_x's were 276, 160, 122, 80, 64, 42, 32, 21,

4, 10, 12, 7. Taking these as a frequency distribution for $x = 0, 1, 2$, etc., the mean is 2.13012, the variance 5.987889. Leading to $c = 0.552164$, and $r = 1.176175$. To the nearest integer the values given are 246, 187, 131, 89, 60, 40, 27, 18, 12, 8, 5 and 9. The goodness of fit is contemptible, as it must be having regard to the wild fluctuations at ages over 100. Even if one clubs together the last four values, P cannot be persuaded to rise above .03. Still the result is less grotesque than one might have expected.

In the following table are shown the 'actual' values, those calculated on the 'proneness' hypothesis, those derived from the smoothed life table based on the experience (*op. cit. p.* 45).

Age	*Actual*	*Proneness*	*Life table*
93	276	246.2	233.2
94	160	186.6	176.8
95	122	130.8	130.7
96	80	89.2	94.2
97	64	60.0	66.1
98	42	40.0	45.2
99	32	26.5	30.9
100	21	17.5	21.1
101	4	11.5	14.3
102	10	7.6	9.2
103	12	5.0	5.3
104	7	9.1	6.0

The values of χ^2 are respectively 27.1 and 28.8, both graduations are equally good (or bad) although the assumptions are completely different. On the proneness view, q_x asymptotes to the ultimate value 0.3557, while the graduated life table makes every value of q_x for x greater than 99 more than this and q_{105} is unity. The inference is, *not* that these data confirm the hypothesis but that they do not exclude it. As by age 100 q_x is already within 0.011 of the ultimate value, it would be sufficiently exact to say that from age 100 the population decreases in geometrical progression with a common ratio of 0.65. On that hypothesis the chance a centenarian woman would have of living to be 106 would be about one in thirteen, as compared with nil (on the official table). But the chance of a woman of 93 attaining this age would be only one in 222. Of course from the practical point of view the fact that the expectation of life at all ages over 100 would be nearly 2.4 years so that the fact that annuities would be independent of age, would deter but few purchasers!

The data for male lives in this report are still scantier and the empirical values of q_x at ages over 90 so erratic that we have not ventured to graduate them.

At this point Mr. E. S. Jones, Actuary to the National Debt Office, was kind enough to supply us with the experience of 240 women and 50 men who attained the age of 90 in 1920-22 and continued under observation until death. In the next table (Table 6) we show observed deaths and graduations by Compound Poissons.

TABLE 6

National Debt Office Data. Deaths (1920-22) *observed and calculated by Compound Poisson*

	1920-22			
	MALES		FEMALES	
Age	Obs.	Compound Poisson	Obs.	Compound Poisson
90	11	9.1	46	36.0
91	12	11.6	45	46.3
92	7	10.1	29	42.9
93	5	7.3	34	34.6
94	7	4.8	25	25.8
95	2	3.0	21	18.3
96	4 } 8	1.8 } 7.1	11	12.6
97	2	2.3	11	8.4
98	50	50	10	5.5
99			3	2.3
100			4 } 8	2.3 } 9.6
101			..	1.4
102			1	2.3
			240	240
	$\chi^2 = 3.2091$		$\chi^2 = 12.7081$	
	$n' = 4$ $P = .3644$		$n' = 8$ $P = .080$	

The fits are again not unreasonable. For males, using 7 groups and therefore 4 degrees of freedom $P = 0.36$. For females, using 10 groups and 7 degrees of freedom $P = 0.08$. The limiting values of q_x are 0.439 for women and 0.544 for men. Some tests of the ultimate mortalities in non-human experience were not unfavorable. Thus for

Hydra (Pearl and Miner, p. 61) one has[5] (graduated values in backets) :— 18 (17), 12 (13), 6 (7), 4 (3), 1 (1). For starved *Drosophila* (*op. cit.*, p. 64) :— 38 (36), 29 (30), 23 (23), 18 (18), 13 (13), 10 (10), 7 (7), 5 (5), 4 (4), 3 (3), 2 (2), 2 (2), 1 (1) and for the tail 3 (3).

It is hardly necessary to add that such agreements in small samples do no more than show that the method of graduation is not preposterous; they go no way to *prove* that the theory is correct. Take for example the following distribution.

Value	*Frequency*
0	4
1	24
2	24
3	24
4	17
5	4
6	2
7	1
	100

The mean and variance are 2.39 and 2.5779, giving for a Compound Poisson $c = 12.7195$ and $r = 30.3996$. The fit is not unsatisfactory — the theoretical frequencies (to the nearest whole number) are 10, 22, 25, 20, 12, 6.3 and 1. For five degrees of freedom one has a P of more than 0.2. The distribution is of the frequency with which the letter *s* occurs in each of the first hundred lines of *Aeneid* XII. It is true that *s* is a letter frequently doubled so that a Compound Poisson might be expected to give a better fit than a Simple Poisson. It is not true that the success of the experiment throws the least light upon Virgil's method of composition. All that may be claimed as shown by the trials is that if and when numerically adequate data are available, the very simple Compound Poisson formula may justify attention.

Biologically speaking the question whether q_x does tend to an ultimate value far short of unity is interesting. Practically speaking, although we think that the chance of an 'Old Parr' emerging under the favorable modern environment is not less than in Stuart times, it is a chance

[5] For *Hydra* we took deaths in five day sets from age 125-129 days; for starved *Drosophilia* deaths in hours from age 50 hours.

without much actuarial importance. It is, if q_x tends to 0.5, a chance of not much more than $(0.5)^{50}$ that a modern centenarian will beat Parr's record.

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GROWTH IN BODY WEIGHT DURING THE FIRST TEN DAYS OF POSTNATAL LIFE

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THE body weight of the newborn infant has been a matter of medical interest for upwards of a hundred years. In consequence, many research papers relating to the problem have been published, and numerous generalizations drawn therefrom have become commonplace among medical practitioners and others concerned with the physical development of the child. As examples of these commonplace generalizations it will suffice here to mention the following:

1. Male infants exceed female infants in mean birth weight.

2. The mean birth weight of first-born infants is less than that for later-born infants.

3. A weight loss occurs in the typical newborn infant during approximately the first three days following birth.

4. This early postnatal loss in weight is due in part to physiological or chemical factors and in part to extraneous or mechanical factors.

5. There is a gradual increase in mean weight from about the fourth postnatal day forward.

6. The equivalent of birth weight is regained, on the average, during the latter half of the second postnatal week.

7. Heavy infants tend to show greater postnatal loss in weight, and to regain birth weight more slowly, than infants who are light at term.

8. Infants given complemental feedings during the first few days following birth show a reduced initial loss in weight and regain birth weight at an earlier age.

It is the purpose of the present paper, first, to review the foundation for the above generalizations in the American research literature,

secondly, to test several of the generalizations simultaneously, i.e., in terms of one series of data and, thirdly, to compare the experimental findings obtained with parallel findings from both the American and the non-American research literature. In short, the general aim of this paper is to critically examine, and to some extent augment, that sector of research on the full-term, nonpathological infant which treats growth in body weight during the first two weeks of postnatal life.

LITERATURE

The research literature relating to the course of human growth during the first fourteen days of extra-uterine life is voluminous. Even when attention is confined to the physically normal infant at term and to growth for the single item total weight an extensive list of investigations is available. It is beyond the scope of this paper to review other than the American studies[1] or to be concerned with other problems than the growth in body weight of so-called "normal" infants.

The oldest study found to qualify for review appeared in 1881. In February of this year Evetzky (16) published a paper on the birth weight of infants and on their growth in weight during the first year of postnatal life. The paper was based on weighings made at the New York Infant Asylum by Dr. Anna Angell, Resident Physician.

Analysis of the weight values obtained at birth — for fifty-seven male infants and forty-five female infants — gave mean birth weights of 3,301 gm. for males and 3,197 gm. for females.

From birth on, a decreasing number of the infants were re-weighed at the end of each week. Seventy-six infants were re-weighed at the end of the first week and seventy-one at the end of the second week. Unfortunately, in the analysis of these week-by-week data the sexes were not differentiated.

A loss in mean weight of 31 gm. was found to occur between birth and the close of the first postnatal week. For the second postnatal week there was a gain in mean weight of 81 gm., making the mean weight at two weeks of age 50 gm. higher than the mean weight at birth.

Evetzky also found that of the seventy-six infants weighed at birth and re-weighed at the termination of the first postnatal week, 50 per cent showed a loss in weight while 45 per cent showed a gain. This implies, of course, that by one

[1] In the interest of historical perspective, however, it should be noted that a considerable body of European research antedates the earliest American study. For a review of early European research on the problem of growth in body weight during the first two weeks following birth, see E. Ingerslev (27, p. 777-799). For a review of early European research on factors related to weight at birth, by the same author, see p. 705-715.

week of age 50 per cent of the group under study had either attained or exceeded their respective birth weights.

Evaluated as probably the first report of American research on the problem, this study has considerable merit. From the standpoint of rigorous research, however, its findings can only be regarded as suggestive. Assuming that body weight was always determined with the infant nude and that the infants were all full-term and of northwest European descent, one still is faced with queries as to the freedom of the sample from significant infant and maternal disease conditions, as to whether the initial weight values were taken immediately following birth or sometime after washing, as to the physiological state of the infant at times of repeated weighings, and as to whether the infants were entirely breast-fed.

In 1885 Stockton-Hough (41) published an analysis of anthropometric data accumulated at the Philadelphia Hospital, Blockley, during the years 1865-1872. The data included body weight values on 712 newborn white infants — 382 females and 330 males.

The findings were presented in three tables. A synthesis and partial re-working of the "weight" columns of these tables yields the following tabulation:

	Males		*Females*	
Pregnancy	Cases	Mean weight	Cases	Mean weight
		(*kg.*)		(*kg.*)
First	207	3.33	216	3.02
Second	61	3.52	95	3.40
Third	22	3.80	24	3.54
Fourth to tenth	40	3.53	47	3.37
Entire series	330	3.43	382	3.19

It will be noted that newborn infants from first pregnancies are definitely lighter in average weight than infants from later pregnancies, and that newborn males of each pregnancy grouping are consistently heavier in average weight than newborn females.

The report gives no answer to such questions as: Were all the infants full-term? Were racial and socio-economic proportions relatively constant for each pregnancy order? Was body weight determined before or after the newborns were washed?

While Stockton-Hough was solely concerned with factors influencing weight at birth, his study is pertinent since it indicates that those who investigate growth in weight for successive days or weeks following birth should take into account the factors of sex and parity.

Morse (31) reported a study in 1886 dealing with the birth weight of infants and their growth in weight during the first year following birth. The portion of the study relating to birth weight was reduced to a single sentence: "From personal and authoritative knowledge I am able to find 7¼ pounds the average weight of boys, and 7 1/20 pounds the average weight of girls at birth." (P. 393.)

Growth in weight during the first year was investigated "by weighing one hundred and eight children twice a day from birth onwards." (31, p. 393.) The findings for the first two postnatal weeks were as follows:

> "At first there is a loss of weight, and it is not until the ninth day that the child has regained its weight at birth. After the ninth day the equilibrium is re-established, and there is a gradual increase..." (p. 393).

The limitations of this report are obvious. The sample of infants is inadequately described, the conditions of weighing are not discussed, and the findings are given in general and largely nonquantitative terms.

In 1887 Chaille (13) published a paper which was intended to help parents "estimate aright the progress which the ordinary average baby ought to make." (P. 893.) With reference to growth in body weight during the first month of postnatal life, he stated:

> "During the first three days of life there is always a loss of weight which should be fully regained by the seventh day...During the next three weeks there should be a gain of at least from two to four ounces every week." (P. 910.)

There is no mention of the number of observations on which this finding is based, nor is it clear that the finding was derived from original research.

A paper on infant loss in weight during the first few days following birth was contributed by Townsend (44) in 1887. Daily weight records selected from the files of the Boston Lying-in Hospital were the main body of data analyzed. The criteria of selection and the number of subject-records selected are indicated in the following citation:

> "Leaving out the partly and wholly bottle-fed infants, the premature, and those who died or left the hospital within a few days, and those whose mothers had acute diseases, there were at the Boston Lying-in Hospital, between May 1st, 1885, and July 1st, 1886, 231 infants entirely breast-fed from birth till discharge from the hospital, generally on the fourteenth day; of these, 140 were from primiparous mothers and 91 from multiparous mothers." (P. 158.)

It is not stated whether the percentage of males and females was constant for the two parity groups.

The mean loss of weight for the 140 infants of primiparae was found to be 296 gm.; the corresponding figure found for the 91 infants of multiparae was 253 gm.

Townsend next considered the extent to which certain extraneous factors may account for this early postnatal loss. His approach and findings were as follows:

> "As the birth-weight is taken before the baby is washed and dried, it is evident that a portion of the loss...is accounted for by casix, liquor, mucus, and blood, with which the baby is more or less bedaubed at birth.
>
> "To determine this factor four infants were weighed at birth and again when washed and dried; in none of these cases was meconium or urine passed before the second weighing. The average loss was...47.5 grammes, the least

> being...25 grammes, the greatest...100 grammes. Another factor in this decrease of weight is, of course, due to the loss of other extraneous matter present at birth, that is, the meconium and urine; these, in a still-born child, were found to amount to 45 grammes, but as fully half as much again was lost during delivery." (P. 158.)

It was concluded that there is a remaining portion of the loss in body weight which is essentially physiological. This loss was considered due "first to the tardy secretion of milk, and in some cases is increased by the abnormally long continuance of colostrum in the milk and secondly to the feeble condition of the infant at birth." (P. 160.)

In the regaining of birth weight, Townsend reported that 60 per cent of the 140 infants of primiparae and 63 per cent of the 91 infants of multiparae reached or surpassed their respective birth weights on the fourteenth day.

In 1896 Holmes (25) made a synthesis of available research on the physical growth of the child. A citation from his paper in regard to growth in weight during early infancy reads:

> "During the first three or four days after birth, there is a normal loss of weight of between 6.15 and 6.96 per cent. The average loss of weight is about 222 grammes. This is followed by a rapid increase in weight, which is greatest during the second month." (P. 202.)

It would appear that the figures for this statement were obtained either from unpublished American research or, more probably, from European research.

A study of the physical growth of New York children covering the period from birth to four years of age was reported by Holt (26) in 1897. The measurements taken included nude body weight.

The mean weight for each sex at birth was calculated from 1,158 consecutive records for full-term infants (590 male and 568 female) on file at three New York maternity hospitals. The mean values obtained were 3.43 kg. for males, and 3.26 kg. for females.

A mean curve of weight for the first twenty days of postnatal life was derived from daily weight records (original) taken upon 100 healthy, nursing infants, fifty of each sex. Both male and female infants were found to show a mean loss of 11 per cent of birth weight by the end of the second day. This loss was observed to be regained by the tenth day.

Griffith and Gittings (18) published a major investigation on "The weight of breast-fed infants during the first two weeks of life" in 1907. Their study was made at the Preston Retreat, Philadelphia, a confinement institution which received "only married women from the working classes." (P. 321.)

Analyses for weight at birth in relation to sex and parity were made using weight values obtained from 226 infants "apparently normal and not premature." The average birth weight was found to be 3,494 grams for 111 males, 3,418 grams for 115 females, 3,129 grams for 68 primiparae, and 3,479 grams for 158 multiparae. Thus the males exceeded the females in average weight at birth by 76 grams, and

the average birth weight of infants of multiparae exceeded that of infants of primiparae by 350 grams.

Growth in weight during the first two weeks following birth was studied with a carefully selected group of 95 infants (44 males, 51 females). These infants were all full term, healthy, born from healthy mothers having normal labor and puerperium, and nursed only at the breasts of their own mothers. "The infants were weighed immediately after birth, and again after they had been washed. They were then weighed every subsequent day at the same hour as that of birth." (P. 329.) Findings for the total group were as follows: average weight at birth 3,464 grams, average weight after bath 3,444 grams, average loss during bath 20 grams, average lowest weight reached 3,154 grams, average loss below birth weight 310 grams. Study of the amount of weight loss in relation to parity and birth weight yielded the conclusions, first, that infants weighing over eight pounds at birth show greater loss than infants weighing less than seven pounds and, secondly, that infants of primiparae show a greater average loss than infants of multiparae. Tabulation was made of the average loss or gain per day, for the infants of each sex, throughout the first postnatal week:

Postnatal day	*Average loss or gain*	
	Males	Females
1	—125.9	—122.5
2	— 71.7	— 57.1
3	11.3	9.9
4	43.9	43.1
5	30.9	40.3
6	30.1	26.7
7	5.4	35.7

This tabulation gave the following findings: (1) the average loss of weight during the first forty-eight hours of postnatal life was 198 grams, or 5.5 per cent of birth weight, for males, and 180 grams, or 5.4 per cent of birth weight, for females; (2) the average gain between forty-eight hours following birth and the end of the seventh day (168 hours) was 122 grams, or 3.4 per cent of birth weight, for males, and 156 grams, or 4.6 per cent of birth weight, for females; (3) the average loss during the first twenty-four hours approximated 61 per cent of the average derived from the maximum loss registered by each individual — this latter average, as previously noted, was 310 grams; and (4) the average weight at the end of the seventh day was less than the average weight at birth by 76 grams, or 2.1 per cent, for males, and 24 grams, or .7 per cent, for females.

Supplementary experimentation was made in order to discover whether the loss in weight after birth (or at least after the initial bath) can be prevented "by early

and abundant feeding." The subjects were forty additional infants. All were full term, of healthy mothers with labor and puerperium normal, and healthy throughout. Average birth weight was 3,239 grams and average weight after bath 3,206 grams. The group was wet-nursed regularly from birth to women in the Retreat who had recently given birth to children. "The nursings were every four hours until the maternal milk was secreted, after which wet-nursing ceased. The daily weighing procedure was as for the main experimental group." (P. 343.) In contrast with the average initial loss of 310 grams for the main experimental group, the average loss for this special group was reduced to 153 grams. Birth weight was regained by the seventh day for 26.3 per cent of the main experimental group and for 35.0 per cent of the special group; by the tenth day for 47.4 per cent of the main experimental group and for 52.5 per cent of the special group; and by the fourteenth day for 67.4 per cent of the main experimental group and for 77.5 per cent of the special group. It was concluded that "while the initial loss of weight in a newborn infant cannot be entirely prevented, it can be materially lessened by the exhibition of the milk of another nursing woman until the mother's secretion has been established, yet that this offers no very great advantage, and certainly the difference in the rates of gain does not justify the administration of any artificial food during the first day of life." (P. 344.)

Griffith and Gittings' study has definite scientific merit. The subjects employed were carefully selected and described, the data were accumulated under adequately controlled conditions, and the treatment of the problem was both straightforward and comprehensive. It should be noted, however, that the averages given in the tables for weight loss in relation to parity and to birth weight appear to be inconsistent with the general averages for weight loss.

In a discussion of the above paper by Griffith and Gittings, Dr. Jacobi stated that it was his practice to feed infants from the time of birth and to spare them the difficulty of digesting colostrum. His position on the weight loss was: "It is mostly water they lose with salts, and that is a very serious matter, for the tissues dry up...The proper thing to do is to give them plenty of water. Whether you want to add 10 or 12 per cent of properly prepared cow's milk to it—I say properly prepared — is for each one to decide; I think it is a good thing. If you do this, the babies will not lose more than a few ounces in the first week, if at all." (18, p. 347.)

A study of the relation between weight at birth and rate of growth in weight during the first two weeks of postnatal life was reported by Hammett (22) in 1918. The data were collected from "the records of the Boston Lying-in Hospital of the weights of five hundred and thirty-seven infants on the 1st, 3rd, 5th, 7th, 9th, 11th and 13th days after birth, excluding from consideration those whose food supply was derived either wholly or in part from sources other than the maternal breasts. Due care was taken throughout as to uniformity of conditions when weighing." (P. 397.)

The type of analysis made may be readily gleaned from the following tabulations:

Percentage change in weight from the initial (first day) weight

Weight group (*pounds*)	Subjects	Postnatal day			
		3	*7*	*11*	*13*
5- 6	100	—4.0	—0.4	3.9	6.0
6- 7	100	—4.7	—1.1	2.8	4.4
7- 8	100	—4.4	—1.1	2.7	4.6
8- 9	100	—5.1	—2.4	0.9	2.1
9-10	100	—7.2	—5.9	—4.0	—2.9
10-11	37	—7.4	—6.4	—4.7	—3.6

Percentage of individuals recovering to or over the initial weight

Weight group (*pounds*)	Subjects	Postnatal day			
		3	*7*	*11*	*13*
5- 6	100	19	50	75	82
6- 7	100	8	45	75	80
7- 8	100	12	39	74	78
8- 9	100	7	30	60	70
9-10	100	2	15	30	35
10-11	37	3	5	11	20

These tabulations are considered to yield the following findings:

1. "The heavier the initial weight the greater the per cent drop in weight after birth. The post-natal per cent loss of weight varies directly with the weight at birth." (P. 399.)

2. "The ability to recover and pass the initial weight after the post-natal decline obviously varies in the same way," i.e., decreases with the increase in initial weight. (P. 405.)

3. "...the heavier the initial weight the slower the rate of growth." (P. 402.) In other words, an increased initial weight is associated with a retardation of growth in weight during at least the first two post-natal weeks.

In closing this paper the author marshaled several observations which tended to support the view "that a birth weight lying between six and eight pounds is indicative of the completion of the intra-uterine growth cycle, that weights under six pounds represent physiologically younger individuals, while those over eight pounds at birth have completed and passed this cycle and are physiologically older." (22, p. 404.)

It is not entirely clear when the initial weighings were made. They are referred to both as having been taken on the first day "after birth" and as having been taken "at birth." The reader will understand, of course, that in the selection of the records for this study, a direct attempt was made to secure series of one-hundred infants whose birth weight fell in one of six successive one-pound intervals.

In a second paper published the same year, Hammett (21) studied the effect of maternal ingestion of desiccated placenta upon the rate of growth of breast-fed infants. His objective was to compare an experimental group of infants fed upon milk produced during the maternal ingestion of dried placenta with a control group of infants subsisting upon milk from mothers to whom this material was not administered and to thereby determine "whether placenta tissue *per se*, when fed to nursing mothers, contains a substance or substances affecting the rate of growth" of breast-fed infants. (P. 569.)

The experimental series consisted of 177 infants. The mother of each infant was given the desiccated placenta prepared in 10 grain capsules, 30 grains being given each day. All mothers selected had a normal parturition course and all weight values utilized were for infants whose sole source of nourishment was the maternal breast.

The control group consisted of the 537 infants reported upon previously. For both the experimental and the control cases the diet of the mothers (except for the dried placenta capsules) and the method of weighing of the infants were the same. Moreover, all the infants were born at the Boston Lying-in Hospital.

As may be seen from the following tabulations, the analysis paralleled that of the previous paper:

Comparison of percentage change in weight from first day

Weight group (*pounds*)	Postnatal day: 3 days		7 days		11 days		13 days	
	Placental	Normal	Placental	Normal	Placental	Normal	Placental	Normal
5- 6	—3.1	—4.0	.6	—0.4	8.8	3.9	12.5	6.0
6- 7	—4.1	—4.7	.4	—1.1	5.2	2.8	7.9	4.4
7- 8	—3.7	—4.4	.1	—1.1	4.3	2.7	5.9	4.6
8- 9	—4.5	—5.1	—1.3	—2.4	2.0	.9	3.3	2.1
9-10	—4.5	—7.2	—3.3	—5.9	—1.7	—4.0	—1.1	—2.9
10-11	—5.4	—7.4	—3.5	—6.4	.9	—4.7	1.5	—3.6

Comparison of per cent recovering to or over initial weight

Weight group (*pounds*)	3 days		7 days		11 days		13 days	
	Placental	Normal	Placental	Normal	Placental	Normal	Placental	Normal
5- 6	17	19	58	50	100	75	100	82
6- 7	12	8	50	45	79	75	95	80
7- 8	0	12	54	39	87	74	89	78
8- 9	5	17	40	30	70	60	79	70
9-10	0	2	33	15	33	30	55	35
10-11	0	3	25	5	75	11	75	20

Hammett finds that the rate of growth of breast-fed infants is enhanced by the maternal ingestion of desiccated placenta since:

1. The postnatal decline in weight is less in amount in the experimental group than in the control group.

2. The gain in weight after the preliminary loss is greater in the experimental or placental group than in the control or normal group, "the mean increase over the normal per cent change in weight on the 13th day being over 60 per cent." (21, p. 571.)

3. The recovery to or over the initial weight occurs earlier for a given percentage of individuals of the placental group than for a like percentage of the normal group.

He concludes that "the maternal ingestion of dried placenta tissue so stimulates the tissues of the infants feeding upon the milk produced during this time, that unit weight is able to add on greater increments of matter, from day to day, than can unit weight of infants feeding on milk from mothers not ingesting this substance." (P. 572.)

Ramsey and Alley (34) reported an analysis of three hundred clinical weight charts in 1918. The charts were obtained "in the ward for new-born of the University Hospital," Minnesota. The analysis made was stated to have given the following findings:

1. "In 300 new-born infants born in the University Hospital the average weights were, boys 3,391 grams, females 3,276 grams." (P. 409.)

2. "...the average initial loss was 240 grams." (34, p. 411.)

3. "...the average time the loss continued was three days." (P. 411.)

4. "The initial loss in large infants...was not relatively greater than in small ones." (P. 412.)

5. "The average daily gain in weight after the third day was about 20 grams, making a total average gain of 140 grams while in the hospital." (P. 412.)

6. "...about one fourth of the infants regained their birth weight before leaving the hospital on the tenth day." (P. 412.)

This paper afforded no answer to such questions as, Were all the infants full-term? Was there any selection of cases with reference to racial stock of parents, disease conditions of mother, or health of the infant? What were the conditions of feeding and of weighing? There were no tables or graphs. No mention was made of the number of cases for each sex. The finding that the initial loss of weight in large infants is not relatively greater than in small infants stands out as being directly contradictory to the finding of Hammett (22) reported the same year.

A study on the effect of complemental feeding on growth in weight during the first ten days of postnatal life was made by Bachmann (2) in 1923. In the selection of his subjects, Bachmann eliminated infants with congenital syphilis or suspected cerebral injury, also prematures and those artificially fed from birth. The total series selected consisted of 127 infants. All were born at the St. Luke's

Hospital, Chicago. Weighings were made shortly after birth and on successive days before the 10 A.M. feeding. Seventy-seven infants were used as the experimental group, while the remaining 50 infants were utilized as a control group. Each infant of the experimental group was fed 30 c.c. of albumin milk during the first 24 hours following birth, and 60 c.c. of the same on the second, third, and fourth days.

The average weight at birth was 3,161 grams for the experimental group and 3,135 grams for the control group. Average initial loss in weight was 172 grams, or 5.3 per cent, for the experimental group and 282 grams, or 9 per cent, for the control group. Fifty-two per cent of the experimental group and 34 per cent of the control group were found to have recovered birth weight by the tenth day. In the experimental group 28 infants (36 per cent) had attained or exceeded their respective birth weights by the seventh day. In the control group the corresponding figures were only 5 infants, or 10 per cent. These findings were considered to show a clear margin of reduced loss and more rapid regain for the group given supplementary feedings of albumin milk.

In 1929, Bakwin and Bakwin (3) studied the influence of season of year on the weight loss of infants. Their data were obtained from records for 1,708 males and 1,607 females born at Bellevue Hospital, New York City, during the years 1926 and 1927.

The mean weight loss, in percentage of birth weight, was calculated for each sex by months of the year. It was found, for both sexes and for both years, that the mean percentage weight loss tended to be less during the summer months than at other seasons of the year. The authors summarized their findings as follows: "The weight loss begins to diminish in June, remains low during the summer months and starts to rise in October. The weight loss during the summer months was about 15 per cent less than during the winter months, the loss during the summer months (July, August, and September) for both males and females averaging about 7.50 per cent of the birth weight, while during the winter months (January, February, and March) the average was about 8.78 per cent." (P. 863-864.)

Supplementary study was made of seasonal variation in mean weight at birth. The same series of infants was used. Means computed for each month of the two-year period showed no constant seasonal fluctuation in birth weight.

Randall (35), in 1930, investigated growth in weight during the weeks immediately following birth as influenced by "complemental feedings during the prelactation period." His total subjects were "a series of 554 healthy, full-term, breast-fed babies" born at the University Hospital, Iowa City, during the years 1928-1930. (P. 425.) The birth weight of all infants fell between the limits of 2,500 grams and 4,500 grams.

Three hundred and nine of the infants "received one ounce of whole lactic acid milk with added corn syrup after each breast feeding during the first four days of life," while the remaining 245 infants "received one ounce of water at the same intervals. Both groups were given one ounce of water routinely at 8:00 A.M. and 4:00 P.M. All babies were to the breast every four hours after the first twenty-four hours." (P. 426.)

The 245 breast-and-water infants averaged 3,409 grams at birth; showed an initial loss of 240 grams, or 7 per cent; and regained birth weight at 10.2 days of age. The 309 breast-water-and-formula infants averaged 3,349 grams at birth; showed an initial loss of 179 grams, or 5.3 per cent; and regained birth weight at 8.4 days of age. On the basis of these and other findings, it was concluded that "Babies who are given complemental feedings of one ounce of lactic acid whole milk with added corn syrup every four hours during the first four days after birth have a smaller initial loss, start to gain weight more quickly, regain their birth weight earlier, and gain more rapidly during the first two or three weeks of life than those who receive complementary feedings of water." (P. 426.) The general position taken was that "A certain weight loss is physiological after birth and occurs regardless of whether food is given or not." (P. 427.)

In a supplementary reference to loss of weight in infants of primiparae versus those of multiparae, Randall noted: "Babies whose mothers had not previously nursed lost more weight than those of experienced mothers . . . The earlier onset of lactation in women who have previously suckled children is probably an important factor in determining this difference." (P. 426.)

Other studies on the effect of complemental feeding on growth in weight during the first two postnatal weeks were reported by Kugelmass, Berggren and Cummings (28) in 1933, Halpern (20) in 1934, and Crawford (15) in 1935. Kugelmass and his co-workers took the position that the initial loss of weight in the newborn was unnatural (being unparalleled in the rest of the animal kingdom), harmful (giving evidence of semistarvation), and largely preventable. The preventive treatment they employed was an isotonic solution containing 6 per cent gelatin in water, 3 per cent dextrose, and 0.5 per cent sodium chloride. This was administered to a series of newborns every two hours for the first three days of life. It was found that when the solution was given during the day the initial loss of weight was 3.4 per cent of birth weight, and when it was given at two-hour intervals day and night the loss could be reduced to 1.7 per cent of weight at birth.

Halpern compared the Kugelmass method of two-hour complemental feedings day and night with the method of administering half certified milk and half water, containing 5 per cent dexti-maltose, with each four-hour breast feeding and wakening the infant for water between feedings. The average initial loss in weight was found to be 145 grams, or 3.9 per cent of birth weight, for the Kugelmass method and 173 grams, or 5.1 per cent of birth weight, for the milk-water method. The Kugelmass formula was given to different infants for periods varying from one to four days. It was found that "The administration of the solution for the first two days of life yielded better results from the standpoint of reduction of initial loss of weight, recovery of birth weight, and effect on subsequent progress than when it was given for the first three days, the first day, or the first four days." (P. 46.) Infants receiving the solution for the first two days, however, did not reach the minimum of 1.7 per cent obtained by Kugelmass and his co-workers. Rather, they showed an average initial loss in weight of 3.7 per cent. With reference to weight at the end of the ninth day of life (time of discharge from the hospital), Halpern notes that the group standing was about the same for both methods of complemental feeding.

Crawford made a comparative study of weight loss and regain for three groups of infants. One group consisted of 118 cases fed lactose citrate solution, another group of 250 cases was fed the gelatin hydrating solution of Kugelmass and his co-workers (one ounce every three hours during first four postnatal days), while a third group of 250 cases was used as a control series. Both hydrating solutions were found to be of distinct advantage during the prelactating period. In the case of the gelatin hydrating solution "the initial loss of weight was only one-third that of the control group and less than half that of the group fed lactose citrate." (P. 1070.) Likewise the weight at discharge was 28 grams above weight at birth for the gelatin hydrating solution, as compared with 85 grams less than weight at birth for the control group and a return to weight at birth for the group fed lactose citrate. Crawford observed that, compared with the lactose citrate, the gelatin hydrating solution was taken more eagerly and retained better. It was also his judgment that this group tended to nurse more eagerly, required less complementary feeding, and to be better satisfied with a four-hour feeding schedule after the third day.

In 1936 Cates and Goodwin (11) analyzed data accumulated on approximately 700 infants weighed at birth and re-weighed on the twelfth day following birth. The infants were born in the Obstetrical Department of the Toronto General Hospital. "Any noted as 'premature' or 'over-term' were excluded." (P. 438.) Weighings were made on a standardized baby scale. The findings for mean weight at birth were 3,450 grams for 341 males and 3,310 grams for 327 females. At twelve postnatal days the means obtained were 3,360 for 295 males and 3,220 for 213 females. It was concluded: "The weight of the male child at birth exceeds that of the female by 4 per cent. In neither sex has the baby at 12 days quite regained its birth weight. Both sexes lose weight and retain it at apparently the same rate." (P. 442.)

The authors did not state whether birth weighings were made before or after washing. Nor was there any discussion of the health of mothers or infants, the feeding procedure employed, or the period over which the data were being accumulated.

Studies have been reported by Riggs (36), Baldwin (7), Brenton (10), Bakwin (4), Bivings (9), Bakwin and Bakwin (6), and Perlstein and Levinson (33) on the relation between birth weight and racial stock; by Faber (17), Brenton (10), Bakwin and Bakwin (3), Bivings (9), and Perlstein and Levinson (33) on the relation between birth weight and season of year in which birth occurred; by Bakwin and Bakwin (6), and Perlstein and Levinson (33) on the relation between birth weight and socio-economic status of the parents; by Stockton-Hough (41), Harris (24), Bakwin and Bakwin (6), and Perlstein and Levinson (33) on the relation between birth weight and pregnancy or birth order; by Griffith and Gittings (18), Harris (23), and Perlstein and Levinson (33) on the relation between birth weight and age of parents or mother; and by Gunstad and Treloar (19) on the relation between birth weight of child and weight of mother. These studies, though concerned exclusively with weight at birth, are not without implications for research on growth in weight during the early weeks of postnatal life. The implications relate both to the selection of subjects for study (e.g., selection of samples that are

relatively homogeneous for racial stock, socio-economic level, order of birth) and to the treatment of data (e.g., making analyses for weight growth in relation to order of birth, season of year, age of mother).

SUBJECTS

The subjects of the present study were 1,038 white infants — 533 male and 505 female. All were born at the University Hospitals, Iowa City, during the three-year period beginning July, 1930, and ending June, 1933.

Every subject had a record which was negative for physical abnormalities and disease conditions.

None of the subjects had been designated "premature." The males had a mean weight at birth of 3,491 grams and ranged in birth weight between 2,548 and 5,304 grams. Their body length at birth (vertex to heel) ranged from 440 to 570 millimeters and gave a mean of 510 millimeters. The females had a mean birth weight of 3,408 grams and ranged in weight between 2,510 and 5,318 grams. Body length at birth for the females ranged from 450 to 575 millimeters and gave a mean of 504 millimeters.

Forty-three per cent of the males and 36 per cent of the females were first-born children. Second-, third-, and fourth-born children made up 40 per cent of the male sample and 42 per cent of the female sample. The remaining 17 per cent of the males and 22 per cent of the females were of fifth or later birth order. With respect to season of year, roughly 29 per cent of the males were born in the spring (March, April, May), 23 per cent in the summer, 23 per cent in the autumn, and 25 per cent in the winter. Corresponding percentages for the females were 28, 24, 21, and 27, respectively.

The infants were essentially breastfed. It was routine hospital procedure to give water to newborn infants at four-hour intervals during the first forty-eight to sixty hours, and at six-hour intervals thereafter. Also, in the event the mother's milk was considered insufficient, it was customary to supplement the breast feedings with a milk-karo solution. This supplementary formula was not used prior to lactation, and was seldom administered before the sixth postnatal day.

The mothers of the subjects ranged in age between 14 and 45 years, in weight between 38.5 and 130.0 kilograms, and in stature between 122 and 183 centimeters. The mean age of the mothers, for the subjects of each sex separately, was approximately 24 years.

In every instance the mother was of Northwest European racial stock (this implies, of course, that cases in which the mother was Jewish were not included) and was free from syphilitic infection, toxemia of pregnancy, and other comparable conditions of ill-health. Information on socio-economic status of the parents was too meager to justify analysis. It was not apparent, however, that any selective factor operated against the hospitalization of a random representation of maternity cases from all socio-economic levels.

DATA

The data were accumulated by the Department of Obstetrics and Gynecology of the University Hospitals, Iowa City.[2] They consist of upwards of 11,000 body weight values. One thousand and thirty-eight of these values were obtained on a like number of newborn infants at birth and the remainder were seriatim observations taken at successive daily intervals. As to the time of making the initial observations, the infants, on delivery, were routinely taken to be "washed" in oil and weighed immediately following. All weight values were determined

TABLE 1

Observations for successive days for each sex and birth-order grouping

AGE (*days*)	NUMBER OF OBSERVATIONS			ALL BIRTH ORDERS
	First-born	Second- to fourth-born	Fifth-born and up	
		Males		
0 to 7	230	211	92	533
8	229	211	91	531
9	228	211	91	530
10	214	187	83	484
		Females		
0 to 7	182	210	113	505
8	180	210	112	502
9	178	210	109	497
10	171	192	99	462

[2] Grateful acknowledgement for access to these data is made to Dr. Everett D. Plass, head of the Department of Obstetrics and Gynecology.

TABLE 2

Mean weight of males and females at birth

INVESTIGATION	MEAN WEIGHT (*grams*)			
	Males		*Females*	
	Cases	Mean	Cases	Mean
Clarke (12), 1786, Ireland				
Dublin Lying-in Hospital. Full-term	60	3342	60	3056
Evetzky (16), 1881, New York				
New York Infant Asylum	57	3301	45	3197
Anthropometric Committee (1), 1883, British Isles: London and Edinburgh	451	3220	466	3130
Stockton-Hough (41), 1885, Philadelphia				
"White" infants	330	3430	382	3190
Morse (31), 1886, Virginia				
Probably private practice cases	50(?)	3300	50(?)	3200
Townsend (45), 1896, Boston				
Boston Lying-in Hospital. Nude weight	500	3428	500	3320
Holt (26), 1897, New York				
Three maternity institutions. Full-term	590	3430	568	3260
Pearson (32), 1900, England				
Lambeth Lying-in Hospital, London	1000	3312	1000	3208
Longridge (29), 1905, England				
Queen Charlotte's Lying-in Hospital				
Infants of primiparae	100	3170	100	3057
Infants of multiparae	100	3356	100	3136
Griffith and Gittings (18), 1907, Philadelphia				
Full-term infants of working mothers	111	3494	155	3418

TABLE 2 (*Continued*)

INVESTIGATION	MEAN WEIGHT (*grams*)			
	Males		*Females*	
	Cases	Mean	Cases	Mean
Robertson (37), 1915, South Australia				
Healthy infants of laboring-class mothers	247	3609	264	3436
Robertson (39), 1915, England				
Maternity Hospital, Birmingham	100	3257	100	3218
Warren (46), 1917, Maine				
Private practice cases. Nude weight	1000(?)	3970	1000(?)	3740
Ramsey and Alley (34), 1918, Minnesota				
Infants born at University Hospital	150(?)	3391	150(?)	3276
Yerington (47), 1918, San Francisco				
Full-term, healthy infants studied by Faber and Murry at Lane Hospital, Stanford University	246	3500	275	3312
Taylor (43), 1919, Minnesota				
Full-term. Predominantly Scandinavian stock	125	3484	125	3377
Faber (17), 1920, San Francisco				
Lane Hospital. Full-term. Nude weight	329	3495	315	3305
Baldwin (7), 1921, Baltimore				
Negro infants	60	3408	70	3340
Brenton (10), 1922, Minneapolis				
Records of three hospitals for 1915 to 1919	952	3377	979	3254
Infants of Swedish parentage		3378		3277
Infants of German parentage		3330		3265
Infants of Jewish parentage		3240		3120

TABLE 2 (*Continued*)

INVESTIGATION	MEAN WEIGHT (*grams*)			
	Males		*Females*	
	Cases	Mean	Cases	Mean
Rowe (40), 1925, Minnesota				
Infants born at Duluth Clinic	327	3374	311	3161
Martin (30), 1930-1931, England				
Queen Charlotte's Lying-in Hospital	3443	3348	3269	3211
Bakwin (4), 1932, New York				
Negro infants	99	3100	88	2916
Clements (14), 1933, Sydney, Australia				
Full-term, healthy infants. Slum, industrial, and residential areas included. Accurate data	289	3685	221	3572
Bakwin, and others (5), 1934, New York				
Parents of moderate income	205	3502	249	3372
Parents from proverty-stricken environment	470	3443	416	3339
Bakwin and Bakwin (6), 1934, New York				
First-born infants	395	3375	417	3222
Later-born infants	423	3540	418	3430
Stuart (42), 1934, Boston				
American or North European parentage	50	3459	63	3374
Bayley and Davis (8), 1935, Berkeley, California				
Parents of business and professional classes	31	3700	30	3350
Cates and Goodwin (11), 1936, Toronto, Canada				
Full-term, normal infants. Accurate weights	341	3450	327	3310
Gunstad and Treloar (19), 1936, Minneapolis				
General Hospital. All uniparous births 1930-1932	1995	3470	1933	3331

with the subjects nude (save for navel dressing). There were repeated values covering a one-week period for the entire series of subjects, while for 91 per cent of the subjects the values extended through to the tenth day of postnatal life. The distribution of this slight decline in the number of values at 8, 9, and 10 days of age is shown in Table 1.

In tabulation of the data, individual records were taken from the hospital files in serial order and accepted for inclusion whenever they fulfilled the specifications thus far noted. That is to say, those records were accepted that applied to normal, white, full-term infants born to healthy mothers, and that carried body weight values covering at least the first seven days following birth.

MEAN WEIGHT AND SEX

It is well established that a sex difference in mean body weight exists at birth. (For confirmation of this statement see Table 2, which gives thirty-five pairs of means drawn from the Anglo-American research literature.) Does this sex difference persist throughout the first ten days of postnatal life? If so, does it tend to become either increased or diminished over the period? In order to secure information on these

TABLE 3

Mean weight of males and females at each of the first ten days of postnatal life

AGE (*days*)	MALES		FEMALES		MALE MEAN MINUS FEMALE MEAN
	Cases	Mean	Cases	Mean	
Birth	533	3491	505	3408	83
1	533	3376	505	3283	93
2	533	3294	505	3207	87
3	533	3274	505	3195	79
4	533	3293	505	3212	81
5	533	3326	505	3246	80
6	533	3366	505	3281	85
7	533	3396	505	3315	81
8	531	3421	502	3341	80
9	530	3440	497	3362	78
10	484	3466	462	3387	79

questions, the data were separated on the basis of sex and then statistically reduced by calculation of the mean weight for each sex at each day of age. The procedure employed in obtaining a given mean was that of summing the particular series of observations being reduced, and dividing the total by the number of observations in the series. Table 3 gives the means obtained for each sex at each day of age, together with a column showing the difference between the mean for the males and that for the females at successive days.

Table 3:

1. Confirms the findings of previous investigators in that it shows males to exceed females in mean weight at birth.

2. Indicates that males surpass females in mean weight on each of the first ten days following birth, and that the average difference in favor of the males is about 82 grams.

3. Shows no marked trend toward either obliteration or exaggeration of the sex difference in mean weight during the age period under study.

Analogous series of means for male and female infants born in England were reported by Martin (30) in 1930-1931. These means were based upon "data respecting children born alive" in the Queen Charlotte's Lying-in Hospital during the four years from 1922 through 1925. Martin noted that the sampling was probably loaded fairly heavily with cases representing the lower socio-economic levels. His means, following conversion from ounces to grams, are reproduced below:

Age	*Males*		*Females*		*Male mean minus female mean*
(days)	Cases	Mean	Cases	Mean	
Birth	3443	3348	3269	3211	137
1	1053	3216	987	3098	118
2	3050	3125	2921	3003	122
3	3118	3089	2936	2976	113
4	3121	3084	2932	2985	99
5	3127	3107	2950	3003	104
6	3144	3121	2958	3016	105
7	3127	3134	2937	3035	99
8	3131	3152	3003	3053	99
9	3107	3180	2957	3075	105

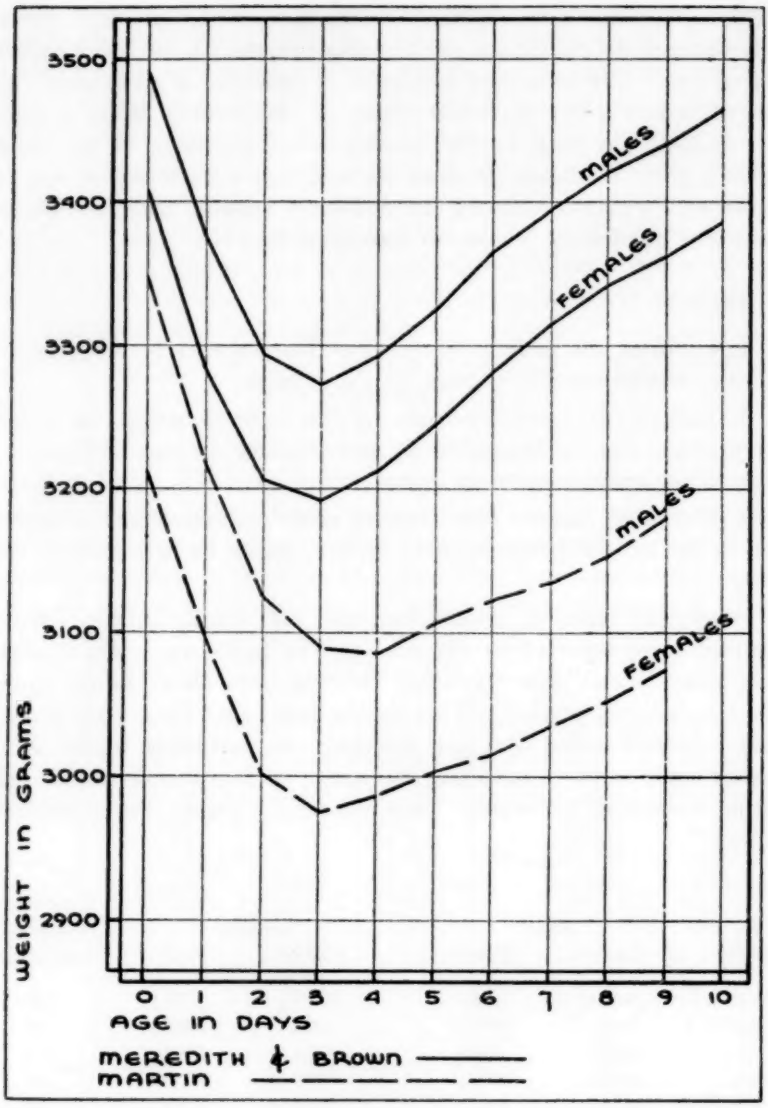

FIG. 1. TRENDS FOR MEAN WEIGHT COVERING THE AGE PERIOD FROM BIRTH TO THE NINTH OR TENTH POSTNATAL DAY

The upper two curves are drawn to values from Table 3 and the lower two curves to values from the tabulation which follows Table 3.

Findings from this tabulation are:

1. Male infants exceed female infants in mean weight on each of the first nine days of postnatal life.

2. The average difference in favor of the males is approximately 110 grams.

3. The differences are more marked between birth and three days of age than from four to nine days of age.

Figure 1 affords a graphic representation of the mean trends for each sex as obtained both by the present study and by Martin. It is clear from this graph that Martin's means for infants born in England are of a distinctly lower order than the means for infants born in Iowa. The necessary information is not available that would enable us to determine to what extent the discrepancy is a function of the racial composition of the two groups and to what extent it is a function of such factors as geographic location or socio-economic status. The lesser rise for Martin's curves following the initial decline suggests that the health level of the infants or the method of infant feeding may have been more inferior for his sample than for the sample used in the present study.

MEAN WEIGHT AND ORDER OF BIRTH

In order to study the relation between body weight and birth order, our data for each sex were subdivided into three birth-order categories. The number of categories was arbitrarily limited to three so that a sufficiently large series of subjects would be retained in each category to yield reasonably reliable mean values.

Body weight means (in grams), specific for sex and for birth-order grouping, were obtained at birth and at each of the first ten postnatal days. These means are given in Table 4.

Curves drawn to each of the six series of values from this table are shown in Figure 2. The findings are:

1. Infants of "second, third, and fourth" birth order have a higher mean body weight than first-born infants at birth and on each of the first ten days following birth. For males, the daily differences fluctuate between 105 and 132 grams, the average difference being 119 grams. For females, the range of the daily differences is 75 to 97 grams, and the average difference 86 grams.

2. Infants of "fifth and higher" birth order exceed infants of "second, third, and fourth" birth order in mean body weight throughout

TABLE 4

Mean weight for males and females of three birth-order groups

AGE (*days*)	FIRST-BORN	SECOND-, THIRD-, AND FOURTH-BORN (*grams*)	FIFTH-BORN AND UP
		Males	
Birth	3396	3525	3653
1	3289	3401	3534
2	3209	3314	3459
3	3188	3296	3440
4	3205	3325	3443
5	3233	3365	3467
6	3275	3404	3506
7	3308	3434	3528
8	3342	3455	3542
9	3364	3472	3557
10	3383	3510	3583
		Females	
Birth	3320	3417	3534
1	3204	3293	3391
2	3136	3217	3303
3	3120	3210	3287
4	3139	3226	3305
5	3175	3262	3331
6	3207	3299	3367
7	3242	3333	3400
8	3275	3353	3425
9	3301	3376	3437
10	3324	3408	3454

the age period from birth to the tenth postnatal day. For males, this excess ranges between 73 and 145 grams, the average difference being 110 grams. For females, the daily advantage for the "fifth and higher" group fluctuates between 46 and 117 grams, and averages 75 grams.

3. The differences between first-born infants and infants of "second, third, and fourth" birth order show no marked trend from day to day

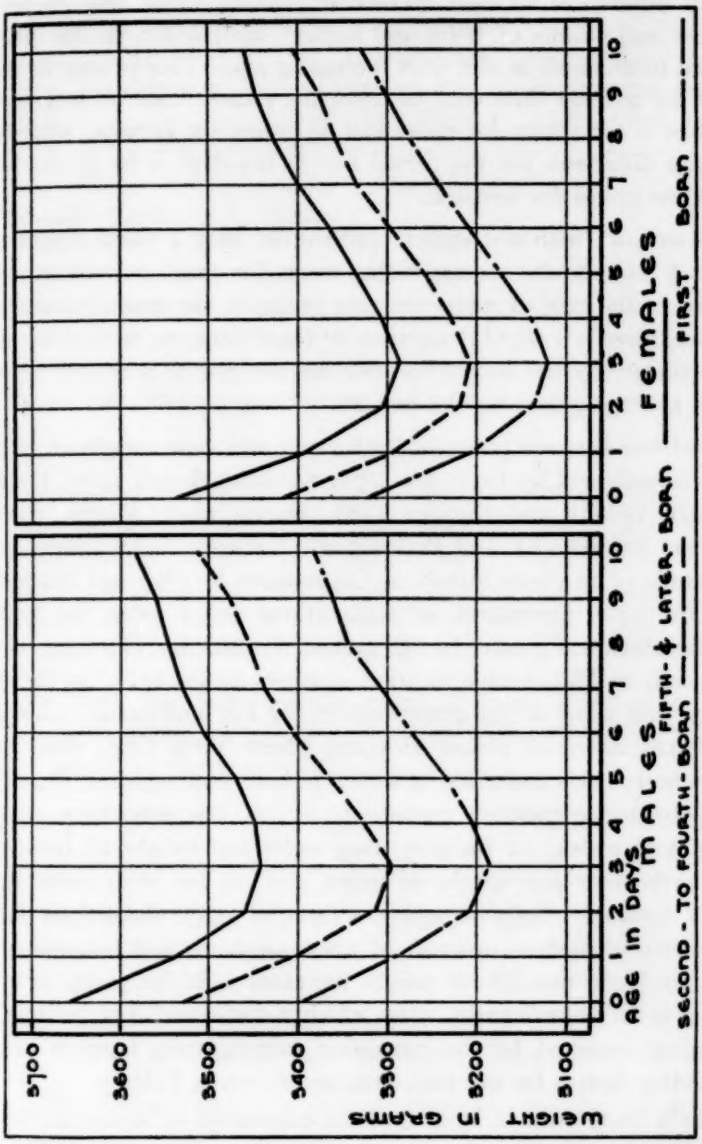

FIG. 2. TRENDS FOR MEAN WEIGHT EXTENDING OVER THE INTERVAL FROM BIRTH TO THE TENTH POSTNATAL DAY
The left panel shows male curves for three birth-order classes. The right panel gives comparable curves for females.

either in the direction of becoming progressively minimized or increased. The daily differences between infants of "second, third, and fourth" birth order and infants of "fifth and higher" birth order, on the other hand, tend to diminish in size with increasing age. This is seen in the fact that the average difference between the means from birth to five days of age is 128 grams for males and 88 grams for females, whereas the average difference for the period five to ten days is 88 grams for males and 60 grams for females.

4. Infants of "fifth and higher" birth order have a mean weight at birth which exceeds the corresponding mean for first-born infants by 257 grams in the case of males and 214 grams in the case of females. Thereafter, there is a slight diminution in the differences so that by the tenth postnatal day the excess has become reduced to 200 grams for the males and 130 grams for the females.

The relation between parity or birth order and mean weight at birth has been investigated by Ingerslev (27), Stockton-Hough (41), Longridge (29), Griffith and Gittings (18), Harris (24), Martin (30), Bakwin and Bakwin (6), and Perlstein and Levinson (33). Ingerslev made a study of newborn infants at Copenhagen in 1876 and obtained a mean for 1,723 primiparae of 3,254 grams and a mean for 1,727 multiparae which was greater by 158 grams. Griffith and Gittings, from a study made at Philadelphia in 1907, obtained means of 3,129 for 66 primiparae and 3,479, or 350 grams higher, for 158 multiparae. Harris, in 1925-1926, analyzed Sloane Hospital (New York City) data for 2,300 newborn males and 2,200 newborn females and reported Pearson Product-Moment correlation coefficients of .21 for pregnancy order and weight of males, .14 for pregnancy order and weight of females, .22 for birth order and weight of males, and .14 for birth order and weight of females. Perlstein and Levinson, in 1937, claimed to have made a statistical study of upwards of 3,000 weight records for newborn infants and found that "Birth weight increases with the parity of the mother up to the seventh parity, after which it decreases." (33, p. 1645.) The findings reported by the remaining investigators, together with corresponding figures for our own data, are shown in Table 5.

Martin's study further lends itself to calculation of means at birth for the three birth-order groupings used in the present study. These means, as may be seen from the following tabulation, are markedly

TABLE 5

INVESTIGATION	FIRST-BORN OR PRIMIPARAE Cases	Mean	MULTIPARAE OR LATER-BORN Cases	Mean	EXCESS OF MULTIPARAE (*grams*)
Males					
Stockton-Hough (41), 1885, Philadelphia	207	3330	123	3573	243
Longridge (29), 1905, England	100	3168	100	3352	184
Martin (30), 1930-1931, England	2041	3238	1485	3460	222
Bakwin and Bakwin (6), 1934, New York	395	3375	423	3540	165
Meredith and Brown, Iowa City	230	3396	303	3564	168
Females					
Stockton-Hough (41)	216	3020	166	3412	392
Longridge (29)	100	3055	100	3133	78
Martin (30)	1946	3139	1384	3280	141
Bakwin and Bakwin (6)	417	3222	418	3430	208
Meredith and Brown	182	3320	323	3458	138

lower than the "birth" values given in Table 4 and show a smaller margin of difference between infants of "second to fourth" birth order and infants of "fifth or later" birth order.

	Order of birth			
	Males		Females	
	Cases	Mean	Cases	Mean
First-born	2041	3238	1946	3139
Second- to fourth-born	1241	3451	1153	3276
Fifth-born and up	244	3488	231	3300

DAY-TO-DAY LOSS OR GAIN IN MEAN WEIGHT

The findings of the present investigation for day by day loss and gain in mean weight are given in Table 6. This table supplies foundation for the following statements:

1. There is a loss in mean weight between birth and three days postnatal age of 217 grams (6.2 per cent) for males and 213 grams (6.3 per cent) for females. For the two sexes combined this loss may be considered to approximate 215 grams or 6.2 per cent of mean weight at birth.

2. During the postnatal age span from the third to the tenth day, there is a gain in mean weight of 192 grams for both males and females.

TABLE 6

Daily loss or gain in mean weight for three birth-order groups and for the entire series

AGE INTERVAL (*days*)	FIRST-BORN (*grams*)	SECOND- TO FOURTH-BORN (*grams*)	FIFTH-BORN AND UP (*grams*)	ALL BIRTH ORDERS (*grams*)
		Males		
0 to 1	—107	—124	—119	—115
1 to 2	— 80	— 87	— 75	— 82
2 to 3	— 21	— 18	— 19	— 20
3 to 4	+ 17	+ 29	+ 3	+ 19
4 to 5	+ 28	+ 40	+ 24	+ 33
5 to 6	+ 42	+ 39	+ 39	+ 40
6 to 7	+ 33	+ 30	+ 22	+ 30
7 to 8	+ 34	+ 21	+ 14	+ 25
8 to 9	+ 22	+ 17	+ 15	+ 19
9 to 10	+ 19	+ 38	+ 26	+ 26
		Females		
0 to 1	—116	—124	—143	—125
1 to 2	— 68	— 76	— 88	— 76
2 to 3	— 16	— 7	— 16	— 12
3 to 4	+ 19	+ 16	+ 18	+ 17
4 to 5	+ 36	+ 36	+ 26	+ 34
5 to 6	+ 32	+ 37	+ 36	+ 35
6 to 7	+ 35	+ 34	+ 33	+ 34
7 to 8	+ 33	+ 20	+ 25	+ 26
8 to 9	+ 26	+ 23	+ 12	+ 21
9 to 10	+ 23	+ 32	+ 17	+ 25

This amount of regain is equivalent to 88 per cent of the male loss and 90 per cent of the female loss.

3. Neither males nor females have a mean weight at ten days of age which is as high as their respective weight means at birth. In percentage terms, mean weight at the tenth day is roughly equal to 99.3 of mean weight at birth.

4. There is no consistent trend in amount of day-to-day loss in mean weight for males of the three birth-order groups. The absolute losses between birth and the third postnatal day, beginning with first-borns, are 208, 229, and 213 grams, respectively. In percentage of mean birth weight for each group, these losses are 6.1, 6.5, and 5.8. For females, there is a trend (not well marked for the middle group) of increasing loss with advancing birth order. The absolute losses are 200, 207, and 247 grams, respectively. Losses in percentage of birth means are 6.0, 6.1, and 7.0.

5. Between the third and the tenth days following birth, the trends of gain in mean weight for the three birth-order groups are complimentary to the trends of loss. Thus the male trend is irregular, showing gains of 195, 214, and 143 grams, while the female trend is one of decreasing amount with advancing birth order, the gains being 204, 198, and 167 grams, respectively.

6. By ten days of postnatal age, first-born females have attained a mean weight equal at 100.1 per cent of their mean weight at birth. Corresponding percentages at the same age for first-born males and for males and females of "second to fourth" birth order are 99.6, 99.6, and 99.7, respectively. For males and females of "fifth and higher" birth orders, the tenth day means in percentage of birth means are of a distinctly lower order — being 98.1 for males and 97.7 for females.

Comparative figures for day-to-day loss or gain in mean weight have been taken from a study by Griffith and Gittings (18), and derived from investigations by Ingerslev (27) and by Martin (30). Ingerslev studied a series of "50 healthy mature children, born of healthy mothers" at a Copenhagen lying-in institution.

> Each child's weight was "first determined immediately after birth, when the child was cleansed and washed. The daily weighings were performed at a fixed hour up to and including the tenth day, with intervals of twenty-four hours, with the exception of the first, of which the time varied from a few hours up to twenty-four. The children were weighed quite naked." (27, p. 784.)

Griffith and Gittings (18) studied 44 male infants and 51 female infants born at a Philadelphia institution receiving "only married women from the working classes." The series consisted of full-term, healthy, breast-fed infants, having healthy mothers with normal labor and puerperium.

> "The infants were weighed immediately after birth, and . . . every subsequent day at the same hour as that of birth. The results give the weights at ages which are multiples of 24 hours. . . . All references in our own observations to 'day' means the 24 hours of life irrespective of the calendar. Thus 'beginning of the third day' would denote always 'beginning of the third 24 hours of life.'" (18, p. 329.)

Martin's data were derived from daily weighings for approximately three thousand infants of each sex born in England. The mothers were predominantly from the lower socio-economic classes. No discussion of the time or conditions of the successive weighings was given.

The day-to-day figures afforded by each of the three studied are as follows:

Age Interval (*days*)	*Ingerslev* (Both Sexes)	*Griffith and Gittings* Males (*grams*)	*Griffith and Gittings* Females (*grams*)	*Martin* Males (*grams*)	*Martin* Females (*grams*)
0 to 1	—83	—126	—122	—132	—113
1 to 2	—82	— 72	— 57	— 91	— 95
2 to 3	— 8	+ 11	+ 10	— 36	— 27
3 to 4	+27	+ 44	+ 43	— 5	+ 9
4 to 5	+29	+ 31	+ 40	+ 23	+ 18
5 to 6	+26	+ 30	+ 27	+ 14	+ 13
6 to 7	+37	+ 5	+ 36	+ 13	+ 19
7 to 8	+51	.....	.....	+ 18	+ 18
8 to 9	+29	.....	.....	+ 28	+ 22
9 to 10	+29	.....	.....	.....	.....

In interpreting this tabulation it is pertinent to note that Griffith and Gittings' finding of a loss in mean weight only to the second postnatal day is consistent with their procedure of delaying the first re-weighing until 24 hours after the initial weighing.

The comparative findings for loss or gain in mean weight from birth to various days following birth are:

1. A loss of roughly 200 grams occurs between birth and the day of minimum mean weight. Specifically, the loss amounts to 173 grams according to Ingerslev;

198 grams for males and 179 grams for females according to Griffith and Gittings; 217 grams for males and 213 grams for females according to the present study; and 264 grams for males and 235 grams for females according to Martin.

2. This loss is not clearly greater or less for first-born infants of primiparae than for multiparae of infants of later birth order. Longridge (29) weighed 400 English-born infants—100 for each sex of primiparae mothers and 100 for each sex of multiparae mothers—immediately after birth and on the evening of the third day. He obtained mean losses of 213 grams for males and females of primiparae and of 220 grams for males and 177 grams for females of multiparae. The mean losses obtained in the present study are 208 grams for first-born males, 200 grams for first-born females, 224 grams for later-born males, and 221 grams for later-born females.

3. Mean birth weight is not regained by the close of the first postnatal week. Mean weight seven days following birth has been found to be less than mean weight at birth by 31 grams in Evetzky's study of 76 infants at New York, by 54 grams in Ingerslev's study of 50 infants at Copenhagen, by 77 grams for males and 23 grams for females in Griffith and Gittings' study of 95 infants at Philadelphia, by 95 grams for males and 93 grams for females in the authors' study at Iowa City, by 167 grams for males and 176 grams for females in Robertson's (37) study of 136 Australian-born infants, and by 214 grams for males and 176 grams for females in Martin's study of over 6,000 English-born infants.

4. On the whole, mean weight at the tenth postnatal day approximates mean weight at birth. Ingerslev found Copenhagen infants to exceed mean birth weight by 55 grams on the tenth day, while the present writers found mean weight on the tenth day to be 25 grams below birth weight for Iowa males and 21 grams below birth weight for Iowa females. Holt (26) analyzed weight records for 100 healthy infants born at New York and found the loss to be regained by the tenth day, while Ramsey and Alley (34) analyzed weight records for 300 infants born at Minneapolis and found the loss to be regained by the tenth day for only about one-fourth of these infants. Martin found English-born infants to weigh less on the ninth postnatal day than at birth by 168 grams in the case of males and 136 grams in the case of females. Cates and Goodwin (11) studied upwards of 500 infants born at Toronto and obtained weight means for each sex which were 90 grams lower at the twelfth postnatal day than at birth. Randall (35) found 245 healthy, full-term, breast-and-water-fed infants to regain birth weight at 10.2 days of age, and 309 healthy, full-term, breast-water-formula-fed infants to regain birth weight at 8.4 days of age.

5. Mean birth weight is exceeded by the close of the second postnatal week. Mean weight fourteen days following birth has been found to be greater than mean weight at birth by 50 grams in Evetzky's study of 71 infants at Copenhagen, by 67 grams for primiparae and 71 grams for multiparae in Longridge's study of 400 English-born infants, by 90 grams for males and 85 grams for females in Robertson's study of 436 infants at Adelaide, and by 198 grams for males and 142 grams for females in Clements' study of 441 infants at Sydney.

DAY-TO-DAY VARIABILITY IN WEIGHT LOSS AND GAIN

The previous section was restricted to a consideration of loss and gain in mean weight. It was found, for example, that the loss in mean weight of 412 first-born infants (from their mean weight at birth) approximated 110 grams at one day, 205 grams at three days, 85 grams at seven days, and 5 grams at ten days of age. The object of the present section is to supplement these mean findings with an analysis of variability at each age. That is, knowing that first-born infants show a loss in mean weight of 110 grams at one day following birth, such questions are now being asked as, How great is the dispersion about this mean? Are there individuals of one day of age that show losses in excess of 300 grams? Do some individuals gain, rather than lose, between birth and the end of the first postnatal day? What percentage lose more than 200 grams of their birth weight? What percentage lose less than twenty grams?

Table 7 gives variability figures for the first-born subjects (230 male and 182 female) of this study at one, three, seven, and ten days of age.

Selected findings shown in Table 7 are:

1. For approximately 78 per cent of the male cases and 81 per cent of the female cases there is a loss in weight from birth to one day following birth of between 50 and 350 grams. During this same age period between 1 and 2 per cent of both the male and the female cases show gains in weight of upwards of 50 grams. For males, the exact range of deviation at one day of age extends from a loss of 338 grams to a gain to 222 grams. For females, the limits of the "spread" are minus 324 grams and plus 152 grams.

2. At three days of age the male range is from a loss of 524 grams to a gain of 100 grams. Roughly 33 per cent of the cases scatter between a gain of 100 grams and a loss of 150 grams. For another one-third of the cases there is a loss in excess of 250 grams. The female range at three days of age is from 585 grams below birth weight to 84 grams above birth weight. Thirty-three per cent (same percentage as for males) either show a gain in weight or a loss of less than 150 grams, while 28 per cent show a loss of upwards of 250 grams.

3. The range at seven days of age is minus 452 grams to plus 272 grams for males and minus 412 grams to plus 214 grams for females. There is a loss exceeding 150 grams for 28 per cent of the males and 25 per cent of the females. Approximately 10 per cent of the males and

TABLE 7

Variability of first-born infants in loss and gain on birth weight at one, three, seven, and ten days of age, respectively

LOSS AND GAIN INTERVALS (*grams*)	MALES		FEMALES	
	Number	*Per cent*	*Number*	*Per cent*
	One Day			
+150 to +249	1	.4	1	.6
+ 50 to +149	2	.9	2	1.1
— 50 to + 49	48	20.9	32	17.6
—150 to — 51	131	56.9	89	48.9
—250 to —151	42	18.3	51	28.0
—350 to —251	6	2.6	7	3.8
	Three Days			
+ 50 to +149	2	.9	1	.6
— 50 to + 49	15	6.5	16	8.8
—150 to — 51	58	25.2	43	23.6
—250 to —151	78	33.9	71	39.0
—350 to —251	65	28.3	41	22.5
—450 to —351	10	4.3	7	3.8
—550 to —451	2	.9	2	1.1
—650 to —551	..	...	1	.6
	Seven Days			
+250 to +349	1	.4	..	...
+150 to +249	5	2.2	5	2.7
+ 50 to +149	18	7.8	25	13.8
— 50 to + 49	66	28.7	48	26.4
—150 to — 51	76	33.0	58	31.9
—250 to —151	40	17.4	29	15.9
—350 to —251	20	8.7	13	7.1
—450 to —351	3	1.3	4	2.2
—550 to —451	1	.4	..	...
	Ten Days			
+350 to +449	1	.5	2	1.2
+250 to +349	6	2.8	7	4.1
+150 to +249	22	10.3	21	12.3
+ 50 to +149	49	22.9	33	19.3
— 50 to + 49	50	23.3	52	30.4
—150 to — 51	54	25.2	31	18.1
—250 to —151	27	12.6	19	11.1
—350 to —251	4	1.9	4	2.3
—450 to —351	1	.5	2	1.2

16 per cent of the females exceed their birth weight by 50 grams or more.

4. Roughly 37 per cent of both the male and the female cases show a gain on birth weight of 50 grams or more by ten days of age. The upper limit of the gain is 436 grams in the case of males and 380 grams in the case of females. The percentage showing a loss of 50 grams or more is 40 for males and 33 for females. The lower limits of this loss are 443 grams and 373 grams for males and females respectively.

5. Variability increases with age between one and ten days. For males, the range at one day of age is 560 grams and at ten days of age 879 grams. Ninety-six per cent of the cases fall within a 300 gram interval at one day of age while only 71 per cent fall within a similar interval at ten days. For females, the range at one day is 476 grams and at ten days 753 grams. Nearly 95 per cent fall within a 300 gram interval at one day while not more than 68 per cent may be grouped within a like interval at ten days.

Before passing to the next section two explanatory notes are in order. Both notes follow from the fact that in this section the interest is that of recognizing and concretely illustrating variability and not that of elaborating minor distinctions in variability. First, it should be observed that the variabilities at the ages selected — 1, 3, 7, and 10 days — are considered to provide a reasonably adequate representation of day-to-day variability over the entire interval from birth to the tenth day following birth. Secondly, it should be stated that variability figures for infants of the other two birth-order groups are not considered sufficiently different from those for first-born infants to warrant their presentation.

DURATION OF LOSS IN WEIGHT

Individual differences in the duration of weight loss have been studied by Ingerslev (27), Griffith and Gittings (18), and Halpern (20). Ingerslev found the duration of initial weight loss to vary from one day to six days and to continue to one day for 2 per cent of the cases, two days for 40 per cent, three days for 28 per cent, four days for 12 per cent, five days for 12 per cent, and six days for 6 per cent. Griffith and Gittings reported losses extending to one day for 1 per cent of their cases, two days for 8 per cent, three days for 37 per cent, four days for 35 per cent, and five days or more for the remaining 18

per cent. Halpern cites one case in a control group of 75 infants and three cases in an experimental group of 75 infants that showed no initial loss of weight.

For the series of subjects (533 male infants and 505 female infants) employed in the present study, Table 8 itemizes the individual differences in duration of weight loss. It will be seen according to this table that:

1. Of males 1.5 per cent and of females 1 per cent show no loss in weight whatever during the first ten days of postnatal life.

2. Of males 34.5 per cent and of females 39.6 per cent show either no loss or a loss not exceeding two days in duration.

3. Only 37 per cent of males and 33.5 per cent of females have a loss which coincides in duration with the day-to-day loss in mean weight.

TABLE 8

Duration of loss in weight for 533 *male infants and* 505 *female infants*

DURATION (*days*)	ENTIRE SERIES		BIRTH-ORDER GROUPS		
	Number	*Per cent*	First-born	Second- to fourth-born (*per cent*)	Fifth-born and up
			Males		
0 (no loss)	8	1.5	1.7	.9	2.2
1	38	7.1	9.6	5.2	5.4
2	138	25.9	20.9	31.3	26.1
3	197	37.0	36.5	41.7	27.2
4	108	20.3	20.0	16.6	29.3
5	36	6.7	9.6	2.8	8.7
6	6	1.1	1.3	.9	1.1
7	2	.4	.4	.5	...
			Females		
0	5	1.0	1.6	.9	...
1	26	5.1	6.6	4.3	4.4
2	169	33.5	30.2	36.7	32.7
3	169	33.5	34.7	33.8	31.0
4	91	18.0	20.3	16.2	17.7
5	29	5.7	4.4	5.7	8.0
6	11	2.2	1.1	1.9	4.4
7	3	.6	.5	.5	.9
8	2	.4	.5	...	.9

4. Of males 28.5 per cent and of females 26.9 per cent show a loss having a duration of four days or more.

5. Eighty-three per cent of males and 85 per cent of females have a loss duration of two, three, or four days.

6. The minimum weight during the first ten days of postnatal life is always reached prior to the ninth day.

7. There are no marked differences in the duration of weight loss for infants of the three birth-order groups. A tendency is observed for the loss to continue longest for infants of "fifth and higher" birth order, to be intermediate for first-born infants, and to have the shortest duration for infants of "second to fourth" birth order. For example, there is a loss of four days or more duration for roughly 21 per cent of "second to fourth" born males, 31 per cent of first-born males, and 39 per cent of males of "fifth and higher" birth order. Corresponding percentages for females are 24, 27, and 32.

Ramsey and Alley found "the average time the loss continued was three days." (34, p. 411.) The mean duration of weight loss as derived from figures reported by Ingerslev and by Griffith and Gittings stands at 3.1 days for the former's sampling and upwards of 3.6 days for the latter's sampling. The findings of the present study are: (1) a weight loss for male infants and for female infants of 2.95 days duration, and (2) a tendency for infants of "second to fourth" birth order to have a weight loss of shortest mean duration — 2.8 to 2.9 days — and for infants of "fifth and higher" birth order to show the greatest mean duration — 3.1 days.

TOTAL AMOUNT OF WEIGHT LOSS

If newborn infants regularly lost weight from the time of birth to the third day following birth, the difference between mean weight at birth and mean weight on the third postnatal day would represent the mean of the individual values for total weight loss. It was shown in the preceding section, however, that the duration of the weight loss is variable and that only about one-third of a group of normal, healthy infants reach their minimum postnatal weight on the third day. Consequently, it is necessary to make separate study of the mean amount of weight loss (regardless of whether minimum weight is reached as early as the first or second day following birth or as late as the fifth or sixth postnatal day) and of individual difference in total weight lost.

The full amount of initial weight loss, without regard to age, has been investigated by Ingerslev (27), Townsend (44), Griffith and Gittings (18), Ramsey and Alley (34), Bachmann (2), Randall (35), Kugelmass, Berggren, and Cummings (28), and Halpern (20).

Ingerslev (27) found the average loss of weight for fifty infants to be 223 grams, or 6.9 per cent of birth weight. "The loss of weight exceeded 300 grams in nine cases, the highest figure being 510 grams . . ." (P. 786). Further, Ingerslev found that the loss of weight was absolutely and relatively greater for males (24 cases) than for females (26 cases), and for infants of primiparae (28 cases) than for infants of multiparae (22 cases). The average loss was 229 grams or 6.9 per cent for males, 217 grams or 6.8 per cent for females, 226 grams or 7.2 per cent for primiparae, and 218 grams or 6.5 per cent for multiparae.

Townsend (44) obtained an average loss of 296 grams for 140 infants of primiparae and of 253 grams for 91 infants of multiparae. The entire series were full-term infants born to healthy mothers.

Griffith and Gittings (18) found an average loss below birth weight of 310 grams or 8.9 per cent for 95 full-term, healthy infants. For 40 additional full-term, healthy cases wet-nursed every four hours from birth until the secretion of the maternal milk to women who had recently given birth to children, these authors obtained an average loss below birth weight of 153 grams, or 4.7 per cent.

Ramsey and Alley (34) analyzed three hundred clinical weight charts for newborn infants and reported that for this series of cases "the average initial loss was 240 grams," or 7.2 per cent.

Bachmann (2) found fifty full-term, healthy infants to give an average weight loss of 282 grams, or 9 per cent of birth weight. For seventy-seven similar cases fed 30 c.c. of albumin milk during the first 24 hours and 60 c.c. of the same on the second, third, and fourth days, he obtained an average loss of 172 grams, or 5.3 per cent of weight at birth.

Randall (35) studied a series of 554 full-term, healthy infants. For 245 cases where each breast feeding was followed by one ounce of water the average initial loss was 240 grams, or 7 per cent of birth weight. For the remaining 309 cases, where each breast feeding was followed by one ounce of whole lactic acid milk with added corn syrup, the average loss was 179 grams, or 5.3 per cent.

Kugelmass, Berggren, and Cummings (28) found that infants fed isotonic solution containing 6 per cent gelatin in water, 3 per cent dextrose, and 0.5 per cent sodium chloride lost 3.4 per cent of birth weight when given the solution at two-hour intervals during the day only, and 1.7 per cent when given the solution at two-hour intervals both day and night.

Halpern (20) fed the Kugelmass solution to 75 infants day and night but obtained an initial loss average of 145 grams or 3.9 per cent of birth weight. An additional 75 infants were given one-half ounce of half certified milk and half water, containing 5 per cent dexti-maltose, with each breast feeding during the first three days and were routinely given water between feedings. These infants showed an average initial loss of 173 grams, or 5.1 per cent.

The mean findings of the present study for total amount of weight lost are as follows:

1. For male and female infants combined (1,038 cases), the mean loss is 246.6 grams, or 7.15 per cent of birth weight. These figures are in close agreement with the figures reported by Ramsey and Alley (34). They are decidedly lower than those obtained by Griffith and Gittings (18) and higher than those for groups receiving complementary feedings.

2. There appears to be no appreciable difference between the mean loss of males and that of females. The male mean is 246.3 grams, or 7.06 per cent, and the female mean 246.9 grams, or 7.24 per cent. Ingerslev, it will be recalled, found the average male loss to be slightly greater than the average female loss.

3. The mean loss tends to increase with advancing birth order. In the case of males, the figures are 236.8 grams for first-born infants, 250.4 grams for infants of "second to fourth" birth order, and 260.7 grams for infants of "fifth and higher" birth order. Corresponding means for females of the three birth-order groups are 232.1 grams, 241.2 grams, and 281.3 grams, respectively. In percentage of mean weight at birth the losses amount to 7.0 per cent for first-born males

TABLE 9

Total weight loss of 533 *male infants and* 505 *female infants*

AMOUNT OF LOSS (*grams*)	MALES		FEMALES	
	Number	*Per cent*	*Number*	*Per cent*
550 to 599	3	.6	3	.6
500 to 549	6	1.1	5	1.0
450 to 499	5	.9	6	1.2
400 to 449	26	4.9	20	4.0
350 to 399	47	8.8	32	6.3
300 to 349	69	12.9	78	15.4
250 to 299	90	16.9	99	19.6
200 to 249	115	21.6	104	20.6
150 to 199	87	16.3	74	14.6
100 to 149	49	9.2	57	11.3
50 to 99	22	4.1	17	3.4
1 to 49	6	1.1	5	1.0
No loss	8	1.5	5	1.0

and females, 7.1 per cent for males and females of "second to fourth" birth order and for males of the "fifth and higher" group, and 7.9 per cent for females of the "fifth and higher" group. The trend of these findings is contradictory to the finding of greater loss for infants of primiparae than for infants of multiparae reported by Ingerslev and by Townsend.

Individual differences in the total amount of weight lost are portrayed in Table 9.

Inspection of this table yields the following information:

1. There is either no loss whatever or a loss of less than 100 grams for 6.7 per cent of the male cases and 5.4 per cent of the female cases.

2. A loss of between 100 and 300 grams characterizes 64.0 per cent of the male infants and 66.1 per cent of the female infants.

3. For 27.5 per cent of the males and 26.9 per cent of the females there occurs a loss of from 300 to 500 grams.

4. A loss in excess of 500 grams is found for 1.7 per cent in the case of males and 1.6 per cent in the case of females. The maximum loss was 598 grams for males and 585 grams for females.

AMOUNT OF WEIGHT LOSS IN RELATION TO DURATION OF LOSS

Certain questions concerning the relation between the duration of weight loss and the amount of weight loss logically present themselves at this juncture. Do the infants that lose weight over a period of five days or longer show the greatest amounts of weight loss? Do the infants with the smallest amounts of weight loss have a loss period of only one or two days duration?

Answers to these questions may be drawn from Table 10. This table shows a slight tendency for infants with a loss duration of one or two days to lose a smaller amount than infants with a loss duration of five or more days. Infants with a loss duration of one day, for instance, show losses of from less than 50 grams to around 300 grams, while infants with a loss duration of five days show losses of from upwards of 100 grams to almost 600 grams.

It should be emphasized, however, that the tendency for amount of loss to increase with duration of loss is very slight. This is evident from gross inspection of Table 10 and from the following itemizations

TABLE 10

Amount of initial weight loss in relation to duration of loss

AMOUNT OF LOSS (*grams*)	DURATION OF LOSS (*days*)								
	0	1	2	3	4	5	6	7	8
Males									
550 to 599	..	..	..	..	2	..	..	1	..
500 to 549	..	..	1	2	..	2	1	..	..
450 to 499	..	..	1	1	3	..	..	..	..
400 to 449	..	..	..	10	11	5	..	..	..
350 to 399	..	..	6	16	19	5	1	..	..
300 to 349	..	1	12	30	18	5	2	1	..
250 to 299	..	3	19	43	17	7	1	..	..
200 to 249	..	6	40	45	19	5	..	..	..
150 to 199	..	7	31	32	10	6	1	..	..
100 to 149	..	12	16	13	7	1	..	..	..
50 to 99	..	7	10	4	1	..	..	..	..
1 to 49	..	2	2	1	1	..	..	..	..
No loss	8	..	..	..	..	..	..	..	..
Females									
550 to 599	..	..	..	1	1	1	..	..	..
500 to 549	..	..	..	2	1	1	1	..	..
450 to 499	..	..	1	4	..	1	..	..	..
400 to 449	..	..	3	5	8	4	..	..	..
350 to 399	..	..	4	13	9	2	3	1	..
300 to 349	..	..	20	28	23	4	2	..	1
250 to 299	..	5	26	39	20	7	..	2	..
200 to 249	..	3	42	43	9	5	2	..	..
150 to 199	..	6	34	18	11	2	3	..	..
100 to 149	..	8	28	10	8	2	..	..	1
50 to 99	..	4	8	5	..	..	..	..	..
1 to 49	..	..	3	1	1	..	..	..	..
No loss	5	..	..	..	..	..	..	..	..

derived by combining the male and female figures for selected portions of the table.

1. Of the infants losing between 100 and 200 grams 12.4 per cent have a loss duration of one day, 40.8 per cent of two days, 27.3 per cent of three days, 13.5 per cent of four days, 4.1 per cent of five days, 1.5 per cent of six days, and 0.4 per cent of eight days.

2. Of the infants losing between 300 and 400 grams 0.4 per cent have a loss duration of one day, 18.6 per cent of two days, 38.5 per cent of three days, 30.5 per cent of four days, 7.1 per cent of five days, 3.5 per cent of six days, 0.9 per cent of seven days, and 0.4 per cent of eight days.

3. Of the infants losing 500 grams or more 5.9 per cent have a loss duration of two days, 29.4 per cent of three days, 23.5 per cent of four days, 23.5 per cent of five days, 11.8 per cent of six days, and 5.9 per cent of 7 days.

AGE AT WHICH BIRTH WEIGHT IS REGAINED

Individual or group differences in the age at which birth weight is regained have been investigated by Ingerslev (27), Evetzky (16), Griffith and Gittings (18), Ramsey and Alley (34), Bachmann (2), Randall (35), and Halpern (20).

Ingerslev (27), for a series of fifty infants, found 31 (62 per cent) to have attained or exceeded their respective birth weights by the tenth postnatal day. Sub-division of the series in terms of sex and of parity gave figures for the percentage of individuals showing regain by the tenth day of 62.5 for males, 61.5 for females, 60.7 for infants of primiparae, and 63.6 for infants of multiparae. For thirty-four infants nursed only by their mothers, Ingerslev found 23 or 67.6 per cent to have equalled or surpassed weight at birth by the tenth day of age. However, for sixteen infants wet-nursed to recently confined women during the first two postnatal days and nursed by their mothers after this age, only 50 per cent were found to have regained by the tenth day.

Evetzky (16) weighed seventy-six infants at birth and at the end of the first week following birth. He found 50 per cent to have reached or exceeded his or her weight at birth by the latter age.

Griffith and Gittings (18), in their study of ninety-five full-term, healthy, breast-fed infants, found birth weight to be regained by the seventh day for 26.3 per cent, by the tenth day for 47.4 per cent, and by the fourteenth day for 67.4 per cent or roughly two-thirds of the cases. Twenty-three of the cases were infants of primiparae and seventy-two infants of multiparae. Fifty-eight per cent of the former and 70.8 per cent of the latter were found to have reached or surpassed birth weight by the fourteenth day. For a series of forty additional subjects, wet-nursed to women who had recently given birth to children until the mother's secretion was established, Griffith and Gittings obtained percentages for birth weight regain of 35 by seven days, 52.5 by ten days, and 77.5 by fourteen days.

Ramsey and Alley (34), from analysis of three hundred weight charts obtained at University Hospital, Minneapolis, reported that "Only about one fourth

of the infants regained their birth weight before leaving the hospital on the tenth day." (P. 412.)

Bachmann (2) made a study of 127 infants with reference to regain of initial postnatal weight. Seventy-seven of the infants were fed 30 c.c. of albumin milk during the first twenty-four hours and 60 c.c. of the same on the second, third, and fourth days. Of this group, 1 per cent regained weight on the fourth day, 4 per cent on the fifth, 9 per cent on the sixth, and 22 per cent on the seventh. The cumulative total of 36 per cent by the seventh day was increased to 52 per cent by the tenth day. The remaining fifty infants of the study were employed as a control group and, therefore, were not subjected to complemental feeding. Recovery of birth weight by this group was found to occur on the sixth day for 2 per cent of the cases, on the seventh day for 8 per cent, on the eighth and ninth days for 10 per cent each, and on the tenth day for 4 per cent. A total of 34 per cent of this group had thus regained initial weight by the tenth day.

Randall (35) found 309 full-term, healthy, breast-fed infants given one ounce of whole lactic acid milk with added corn syrup after each breast feeding during the first four days of life to regain birth weight, on the average, at 8.4 days of age. For a similar sample of 245 infants given only water in addition to breast feedings, the same author obtained an average age for birth weight regain of 10.2 days.

Halpern (20) fed the Kugelmass solution to seventy-five private practice infants at two-hour intervals day and night during the first two or three days of postnatal life. Roughly 9 per cent of the infants had equalled or exceeded birth weight on the third day, 52 per cent on the seventh day, and 56 per cent on the ninth day. For the 56 per cent that had recovered by the ninth day (time of discharge from the hospital) the average age at regain was 5.6 days. A further group of seventy-five infants was given feedings of half certified milk and half water, containing 5 per cent dexti-maltose, at three to four hour intervals during the first three days. Approximately 3 per cent of this group were found to reach or surpass birth weight by three days of age, 31 per cent by seven days, and 50 per cent by nine days. The average age of recovery for the 50 per cent recovering on or before the ninth day was 6.9 days. Halpern noted that the regain status for the two groups at nine days of age was about equal.

Table 11 gives the ages at which different individuals of the sample of 1,038 infants employed in the present study regained their respective birth weights.

Among the findings which may be drawn from Table 11 are the following:

1. By four days of age, 5.7 per cent of the males and 5.0 per cent of the females have a body weight equal to, or greater than, weight at birth. These percentages are higher than those for Bachmann's experimental group and Halpern's control group, but lower than that for Halpern's experimental group.

TABLE 11

Age at which birth weight is regained

AGE BIRTH WEIGHT REGAINED (*days*)	NUMBER	PER CENT	CUMULATIVE PER CENT
	Males		
0 (No loss)	8	1.5	1.5
2	3	.6	2.1
3	4	.8	2.9
4	15	2.8	5.7
5	32	6.0	11.7
6	43	8.1	19.8
7	35	6.5	26.3
8	49	9.2	35.5
9	48	9.0	44.5
10	46	8.6	53.1
Older	250	46.9	100.0
	Females		
0	5	1.0	1.0
3	3	.6	1.6
4	17	3.4	5.0
5	21	4.2	9.2
6	44	8.7	17.9
7	46	9.1	27.0
8	41	8.1	35.1
9	42	8.3	43.4
10	37	7.3	50.7
Older	249	49.3	100.0

2. Approximately 26 per cent of the males and 27 per cent of the females have a body weight at seven postnatal days which equals or exceeds their respective weights at birth. The percentage reported by Griffith and Gittings for their series of ninety-five infants is in agreement with these figures. Other percentages range from 10 for the Bachmann control group, through 35 and 36 for the Griffith and Gittings and the Bachmann experimental groups, to 50 and 52 for the Evetzky series and the Halpern experimental group.

3. Roughly 53 per cent of the males and 51 per cent of the females are found to have regained birth weight by the tenth postnatal day. These regain findings are lower than those obtained by Ingerslev and

markedly higher than those by Ramsey and Alley and by Bachmann for his control series. They are in close agreement with the percentages reported for the Bachmann experimental group and for each of the two groups studied by Griffith and Gittings and by Halpern.

DURATION OF WEIGHT LOSS IN RELATION TO AGE OF REGAIN

The relation between duration of loss in weight and the age when birth weight is regained is portrayed in Table 12. This table shows that:

TABLE 12

Duration of loss on birth weight in relation to age of birth weight recovery

AGE BIRTH WEIGHT REGAINED (*days*)	DURATION OF LOSS (*days*)								
	0	1	2	3	4	5	6	7	8
Males									
0	8	..	..	..	..	..	..	..	..
2	..	3	..	..	..	..	..	..	..
3	..	3	1	..	..	..	..	..	..
4	..	4	9	2	..	..	..	..	..
5	..	8	17	7	..	..	..	..	..
6	..	3	26	14	..	..	..	..	..
7	..	7	11	14	3	..	..	..	..
8	..	3	13	17	15	1	..	..	..
9	..	4	15	16	11	2	..	..	..
10	..	3	12	19	9	3	..	..	..
Older	..	..	34	108	70	30	6	2	..
Females									
0	5	..	..	..	..	..	..	..	..
3	..	3	..	..	..	..	..	..	..
4	..	3	12	2	..	..	..	..	..
5	..	4	13	3	1	..	..	..	..
6	..	3	27	13	1	..	..	..	..
7	..	5	18	19	4	..	..	..	..
8	..	3	14	15	7	2	..	..	..
9	..	1	13	19	7	2	..	..	..
10	..	..	10	12	10	3	2	..	..
Older	..	4	62	86	61	22	9	3	2

1. For 38 males having a loss in weight of one day duration there is recovery of birth weight by four days for 26 per cent, by six days for 55 per cent, and by ten days for 100 per cent. The 26 females in the one-day-loss column show regain of their indiviudal birth values by four days for 23 per cent, by six days for 50 per cent, and by ten days for 85 per cent. The remaining 15 per cent of the female cases do not reach the equivalent of weight at birth until sometime following the tenth day.

2. For 197 males having a weight loss of three days duration there is regain of weight at birth by seven days for 19 per cent and by ten days for 45 per cent. Corresponding percentages for the 169 females that show three-day loss are 22 and 49.

3. Only 17 per cent of the males and 24 per cent of the females in the five-day-loss column recover to their respective weights at birth by the tenth day.

4. Regain of birth weight by the tenth postnatal day occurred for 75 per cent of the male cases and 63 per cent of the female cases showing a loss duration of two days, for 35 per cent of the males and 33 per cent of the females showing a loss duration of four days, and for 0 per cent of the males and 14 per cent of the females showing a loss duration of six to eight days.

RELATION OF WEIGHT AT BIRTH TO LOSS AND GAIN IN WEIGHT

The relationship between the birth weight of infants and their loss and gain in weight following birth has been studied by Ingerslev (27), Longridge (29), Griffith and Gittings (18), Hammett (21, 22), Ramsey and Alley (34), and Martin (30).

Ingerslev (27) distributed a series of fifty infants into three weight groups. Group I consisted of fourteen infants weighing less than six pounds at birth, Group II of twenty-one infants weighing between six and seven pounds, and Group III of fifteen infants having birth weights of more than seven pounds. The total initial weight loss for each infant was obtained and from these values the average weight losses were calculated to be 209 grams for Group I, 224 grams for Group II, and 235 grams for Group III. Ingerslev noted, however, that while the loss was absolutely least for Group I and greatest for Group III, it was relatively greatest for Group I and least for Group III. The exact figures obtained for loss in percentage of birth weight were 7.7 for Group I, 6.9 for Group II, and 6.3 for Group III. On the tenth postnatal day the infants weighing over seven pounds at birth were found to exceed birth weight by an average of roughly 125 grams and infants weighing between six and seven pounds by an average of approximately 71 grams. The infants weighing under

six pounds at birth gave a mean weight 23 grams less than their mean weight at birth. Thirty-six per cent of Group I, 68 per cent of Group II, and 73 per cent of Group III attained or surpassed birth weight by the tenth day.

Longridge (29) obtained an average initial loss of 184 grams for 187 infants weighing under seven pounds at birth, and of 246 grams for fifty-eight infants having birth weights of over eight pounds. More refined analysis gave average losses of 220 grams for male infants of primiparae with birth weights under seven pounds, 276 grams for male infants of primiparae with birth weights over eight pounds, 198 grams for primiparae females below seven pounds, 284 grams for primiparae females above eight pounds, 184 grams for multiparae males under seven pounds, 241 grams for multiparae males over eight pounds, 135 grams for multiparae females below seven pounds, and 206 grams for multiparae females above eight pounds. Longridge concluded that there was a tendency for initial loss to be greater the heavier the infant at birth.

Griffith and Gittings (18) studied weight at birth in relation to loss in weight for a series of ninety-five full-term, healthy, breast-fed infants. Their findings are reproduced in the following tabulation:

Birth weight (pounds)	*Males*	*Loss in weight (grams)*	*Females*	*Loss in weight*
5 to 6			1	156
6 to 7	8	211	16	184
7 to 8	19	252	21	231
8 to 9	13	233	11	324
Over 9	4	309	2	425

They drew the general conclusion that the heavier the full-term infant the greater will be the initial weight loss.

Hammett's studies (21, 22) of the relation between weight at birth and rate of growth in weight during the first two weeks of postnatal life have already been reviewed. It will suffice here (1) to recall that the subjects were 537 infants fed unmodified milk at the maternal breasts and 177 infants fed milk produced during maternal ingestion of desiccated placenta, (2) to present a tabulation synthesizing the essential data, and (3) to make brief mention of the major findings. The tabulation follows:

Weight group (pounds)	*Postnatal day*					
	Third		*Seventh*		*Thirteenth*	
	Normal	Placenta	Normal	Placenta	Normal	Placenta
	Percentage change in weight from initial weighing					
5 to 6	—4.0	—3.1	—0.4	.6	6.0	12.5
6 to 7	—4.7	—4.1	—1.1	.4	4.4	7.9
7 to 8	—4.4	—3.7	—1.1	.1	4.6	5.9
8 to 9	—5.1	—4.5	—2.4	—1.3	2.1	3.3
9 to 10	—7.2	—4.5	—5.9	—3.3	—2.9	—1.1
10 to 11	—7.4	—5.4	—6.4	—3.5	—3.6	1.5

(*Tabulations continued*)

	Percentage of individuals regaining initial weight					
5 to 6	19	17	50	58	82	100
6 to 7	8	12	45	50	80	95
7 to 8	12	0	39	54	78	89
8 to 9	17	5	30	40	70	79
9 to 10	2	0	15	33	35	55
10 to 11	3	0	5	25	20	75

Hammett found: (1) the heavier the initial weight the greater the per cent drop in weight, (2) the lighter the initial weight the earlier the recovery of weight loss, and (3) the postnatal decline may be reduced in amount and accelerated in time of regain through maternal ingestion of desiccated placenta.

Ramsey and Alley (34), in reporting their analysis of three hundred clinical weight charts, stated that they had investigated the question of whether the initial loss of heavy infants was relatively greater than that of light infants and found "The initial loss in large infants . . . was not relatively greater than in small ones." (P. 412.) This finding agrees with that of Ingerslev but is contradictory to the findings of Hammett.

Martin (30) studied birth weight in relation to absolute loss and regain in weight for approximately 3,000 infants of each sex. He found: "The loss of weight during the first days of life is greatest among the largest infants . . . For both males and females the heavier the baby the more weight is lost, but the following gain in weight appears to be the same for each group . . ." (P. 331.) The following tabulation reproduces part of the quantitative basis for these findings:

Weight group (pounds)	*Mean loss from birth to day of minimum*		*Mean gain from day of minimum to ninth day*	
	Males	Females	Males	Females
5 to 6	222	200	72	118
6 to 7	249	240	104	104
7 to 8	281	272	109	118
8 to 9	308	304	104	113
9 to 10	345	340	127	122

In order to obtain some original findings on the relationship between weight at birth and postnatal loss and gain in weight, 40 per cent of the 533 male records employed in the present study were selected for special study. These records were for 107 infants having birth weights of 3,860 grams or more (the heaviest 20 per cent of the series) and 107 infants with birth weights of 3,100 grams or less (the lightest 20 per cent). The "heavy" group was found to be composed of thirty-

three first-born males, forty-three males of second to fourth birth order, and thirty-one males of fifth or higher birth order. Corresponding numbers in the "light" group were 60, 31, and 16, respectively.

Separate analysis was made of the data for each group. Means were obtained at birth and at each of the first ten postnatal days and from these values the mean losses or gains were determined for each day of age. The results are given in Table 13.

TABLE 13

Mean weight, together with loss or gain in mean weight, for the heaviest twenty percent and the lightest twenty percent of 533 *male infants*

AGE (*days*)	"LIGHT" GROUP		"HEAVY" GROUP	
	Mean	Gain or Loss	Mean	Gain or Loss
0 (birth)	2905.3		4138.1	
1	2818.3	—87.0	4003.8	—134.3
2	2745.9	—72.4	3902.9	—100.9
3	2739.7	— 6.2	3880.3	— 22.6
4	2760.9	+21.2	3904.5	+ 24.3
5	2793.3	+32.4	3929.0	+ 24.5
6	2830.2	+36.9	3967.6	+ 38.6
7	2855.2	+25.0	3986.4	+ 18.8
8	2893.0	+37.8	4014.7	+ 28.3
9	2908.3	+15.3	4021.3	+ 6.6
10	2925.9	+17.6	4043.4	+ 22.1

The findings from this table may be summarized as follows:

1. There is a loss in mean weight between birth and three days postnatal age of approximately 166 grams for male infants weighing less than 3,100 grams at birth and 258 grams for male infants having a birth weight in excess of 3,850 grams. These losses are equal to 5.7 per cent and 6.2 per cent of mean birth weight for the respective groups. The loss in mean weight for infants "heavy" at birth is thus found to be both absolutely and relatively greater than the loss in mean weight for infants "light" at birth.

2. During the period from three to ten postnatal days there is a gain in mean weight of 186 grams for the infants weighing less than 3,100 grams and of 163 grams for the infants weighing more than 3,850

grams. This amount of regain is equivalent to 112 per cent of the loss in the former case and 63 per cent of the loss in the latter case. The gain in mean weight for infants "heavy" at birth is thus found to be less than the gain in mean weight for infants "light" at birth.

3. The lightest 20 per cent of the male series employed in the present study have a mean weight at ten days of age equal to 100.7 per cent of their mean weight at birth, while the corresponding figure for the heaviest 20 per cent of the series is 97.7 per cent.

In general, it appears that "light" infants tend to show a smaller amount of postnatal loss in weight and an earlier regain to the equivalent of weight at birth than "heavy" infants.

RELATION OF SEASON OF YEAR IN WHICH BIRTH OCCURS TO LOSS AND GAIN IN WEIGHT

For the purpose of studying seasonal variation in growth in weight during the first ten postnatal days, the subjects of each sex (533 males and 505 females) were divided into four groups on the basis of month of birth. Those born in March, April, or May constituted the "Spring" group, those born in June, July, or August the "Summer" group, those born in September, October, or November the "Autumn" group, and those born in December, January, or February the "Winter" group. Separate analysis of the data for each of these groups yielded the figures given in Table 14.

Selected findings from this table are:

1. Highest mean birth weight was found for the spring months in males and for the winter months in females. Lowest means at birth were obtained for the summer months in males and the autumn months in females. The difference between the highest and lowest means was 67 grams for males and 62 grams for females. This slight tendency for birth weight to be high in winter (females) or spring (males) and low in summer (males) or autumn (females) is at variance with the recently reported finding of Perlstein and Levinson (33) that infants born during the warm months of the year tend to be slightly heavier than infants born during the cold months. On the whole, the findings of the present study may be considered to support the findings of Brenton (10) and of Bakwin and Bakwin (3) that although slight fluctuations occur there is no significant or consistent seasonal variation in birth weight.

TABLE 14

Relation of season of year to birth weight and to loss and gain in weight during the first ten postnatal days

SEASON	CASES	MEAN AT BIRTH (*grams*)	LOSS IN MEAN WEIGHT From birth to 3 days of age (*grams*)	(*per cent*)	GAIN IN MEAN WEIGHT From 3 to 10 days (*grams*)	MEAN AT 10 DAYS In percentage of mean at birth
			Males			
Winter	135	3473	209	6.0	177	99.1
Spring	152	3520	227	6.4	180	98.7
Summer	125	3453	204	5.9	208	100.1
Autumn	121	3486	197	5.7	192	99.9
			Females			
Winter	137	3449	225	6.5	179	98.7
Spring	143	3390	208	6.1	178	99.1
Summer	121	3395	220	6.5	214	99.8
Autumn	104	3387	203	6.0	219	100.5

2. Between birth and the third postnatal day, males born in the winter and spring show a greater absolute and relative loss than males born in the summer and autumn. However, no systematic trend of loss for females from season to season is shown. It will be recalled that Bakwin and Bakwin found "The weight loss during the summer months was about 15 per cent less than during the winter months, the loss during the summer months (July, August, and September) for both males and females averaging about 7.50 per cent of the birth weight, while during the winter months (January, February, and March) the average was about 8.78 per cent." (Pp. 863-864.)

3. During the age period from three to ten days, male and female infants born in the summer and autumn show greater gains in mean weight than males and females born in the winter and spring. The female gains for summer and autumn exceed their gains for winter and spring by about 20 per cent. The male difference is slightly less marked, being around 12 per cent.

4. Male and female infants born in the summer and autumn more nearly approximate their birth means by ten days of age than do male and female infants born in the winter and spring. In rounded figures, means for winter-born and spring-born infants at ten days of age equal less than 99 per cent of corresponding means for birth, while means for summer-born and autumn-born infants of ten days exceed, or closely approximate, 100 per cent of the respective means for birth.

SUMMARY

This paper is intended to constitute a research contribution on the growth of the neonate in body weight. Following a review of the American literature on growth in weight of the full-term, nonpathological infant during the first two weeks of postnatal life, original and comparative findings are presented on the following topics: mean weight and sex, mean weight and order of birth, day-to-day loss or gain in mean weight, day-to-day variability in weight loss and gain, duration of loss in weight, total amount of weight loss, amount of loss in relation to duration of loss, age at which birth weight is regained, duration of weight loss in relation to age of regain, relation of weight at birth to loss and gain in weight, and relation of season of year in which birth occurs to loss and gain in weight.

The experimental data consist of seriatim weight values, covering the period from birth to the tenth postnatal day, for approximately one

thousand full-term, healthy infants of northwest European descent born at the University Hospitals, Iowa City. These data were accumulated by the Department of Obstetrics and Gynecology during the period July, 1930 to June, 1933.

Analyses of the data are made with reference to sex, order of birth, weight at birth, and season of year. Tables are constructed to portray the individual differences, as well as the group trends, with respect to amount of loss, duration of loss, and age of regain. Selected findings are:

1. Male infants consistently exceed female infants in mean weight between birth and the tenth postnatal day.

2. Throughout the period from birth to ten days of age, mean weight is least for first-born infants, intermediate for infants of second to fourth birth order, and greatest for infants of fifth and higher birth order.

3. Day-to-day means show a loss in weight between birth and three days following birth of 215 grams, or 6.2 per cent of mean birth weight. Not every individual conforms to this average trend. Only about one-third of the cases have a loss of three days duration and only about 20 per cent lose between 200 and 250 grams. A few lose to the seventh or eighth day, while a few show no loss whatever. On the third postnatal day, there were infants registering weight losses in excess of 500 grams and there were infants registering weight gains of around 100 grams.

4. The mean amount of weight loss (calculated without regard to the day on which minimum weight was reached) is found to be 247 grams, or 7.1 per cent. The loss is the same for both sexes, but tends to be greater with increasing birth order.

5. Day-to-day means show a gain in weight between birth and the tenth postnatal day of 192 grams. Weight at ten days is thus less than (roughly 99.3 per cent of) weight at birth. While the gain is not different for the two sexes, there is a tendency for first-born infants to regain birth weight earlier than infants of fifth and higher birth order.

6. Around 26 per cent of the infants are found to regain their respective birth weight by the close of the first postnatal week. The corresponding figure for ten days of age stands at 52 per cent.

7. Light infants (infants weighing less than 3,100 grams at birth) are found to show a smaller amount of postnatal loss in weight and an

earlier regain to the equivalent of weight at birth than heavy infants (infants weighing 3,860 grams or more at birth).

8. Infants born in the summer and autumn tend to approximate their birth means by ten days of age, while infants born in the winter and spring reach less than 99 per cent of their birth means. On the whole, the findings for seasonal variation are not as clean-cut as the findings on the other topics considered.

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SEXUAL BEHAVIOR IN THE CHIMPANZEE[1]

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I. INTEREST AND OBJECTIVES

IN THE forefront of human needs is the wise control of sexual behavior and of the quantity and quality of population. For the satisfaction of these necessities our knowledge and understanding of the nature, conditions, and relations of sexual and reproductive phenomena are wholly inadequate. Fortunately research in this field of biology commands universal interest, and its results are promptly seized upon for critical scrutiny, evaluation, and application. The continuing study of chimpanzee behavior, from which the materials of this report are derived, is motivated primarily by interest in human problems and by the conviction that in its sexual and reproductive life this anthropoid ape is sufficiently manlike, amidst experimentally advantageous differences, to render it peculiarly useful as substitute for man in many types of inquiry. For whereas because of social taboos, self-consciousness, modesty, shame, and deception, it is extremely difficult or impossible to study the sexual behavior of man experimentally and objectively, the opposite is true of the chimpanzee and of certain other primates. Through intensive study of the reproductive life of this ape, research leads and methods may be discovered, insights may be achieved, and modes of modification and control developed which will find fruitful application in human social biology. This is the faith which underlies our relatively indirect and comparative attack on problems of sexual behavior. It is not to improve the chimpanzee, nor even to satisfy our curiosity about its patterns of behavior and their mechanisms that we study the organism persistently. Instead, our concern is with the extension of knowledge of life and the improvement of its quality. As experimental material, the ape is a means, not an end.

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Recurrent in scientific literature is the statement that primates differ from many other mammals in that they may mate at any time during the sexual cycle instead of only during a brief period of heat, which is technically termed oestrus. Prolonged observation of the chimpanzee and critical examination of the facts available for other primates, including man, lead us to reject this generalization and to propose in its stead the following working hypothesis and descriptive formula.

The primates, as well as other mammals, exhibit oestrus. With the organic type it varies in periodicity from days to months. The higher the order of behavioral adaptiveness (general intelligence) and the more dominant the male of the species, the wider the range of copulatory responsiveness in the typical sexual cycle and the greater the tendency of the female to respond accommodatingly to his advances irrespective of her sexual status. This generalization is presented tentatively in the light of assured, although limited, knowledge of the pertinent behavior of the chimpanzee and with full realization that it is inconsistent with what is accepted as true for monkey and man. The facts for the former we deem incomplete and misleading; those for the latter, in important respects unreliable by reason of psychological errors of observation, report, and interpretation. Despite certain seemingly unfavorable evidence, we suspect that periodicity of sexual receptivity is as characteristic of the female of the species in monkey and man as in chimpanzee.

In the pages to follow we shall be concerned with both social and individual forms and aspects of chimpanzee sexual behavior. The first is exemplified by the mating pattern; the second, by varied expressions of sexual excitability, responsiveness, receptivity, and desire. A few definitions may lessen our risks of misunderstanding. Mating behavior is a social pattern which may be observed only in interacting individuals. It is a descriptive datum whose value increases as determining and conditioning factors are discovered. By contrast with it, excitability *et al.* are aspects of individual function which we should be able to study and measure in the isolated animal. Actually this has rarely been accomplished. Desire is a form of experience, and in this report we shall limit attention to its behavioral expressions. Sexual excitability is a physiological state which is measurable in terms of response. Sexual responsiveness designates the readiness and capacity of the organism at any given moment to exhibit specific forms of behavior. Receptivity is applicable only to the female: it refers to her state of preparedness to receive the male and to coöperate in mating.

By the psychobiologist, problems of sexual behavior have been neglected, aside from naturalistic description, observations in conjunction with measurement of sexual drive, and the revelations of psychoanalytic method. Yet the understanding of sexual phenomena in their ne[illegible]l, hormonal, and general behavioral relations may be of supreme in[illegible]t-ance for the profitable conduct and regulation of our lives. What, then, are the factors in control of sexual responsiveness, receptivity, desire, and mating? How may they be discovered, isolated, measured, modified? Are methods available for the analytical and quantitative study of desire or responsiveness? For desire, certainly not, save in the introspective procedures, which are restricted to human subjects. For responsiveness, yes, as crude first steps toward the necessary and ideal.

II. METHODOLOGICAL CONSIDERATIONS

Among the methods of studying sexual responsiveness, which in recent years have been devised especially for the measurement of "sexual drive," are those which employ the principles of balanced motives, presence or absence of response, frequency of response, and the rating of significant response items. A summary account of such methods and of current knowledge may be found in Stone (1932). Highly important contributions of fact and method have been made by Moss (1924), Stone and Sturman-Huble (1927), Warner (1927), Warden (1931), Hemmingsen (1933), Ball and Hartman (1935), and Ball (1937, 1937a). But of these, Ball and Hartman alone have observed and discussed primate behavior.

Beginning our study of the chimpanzee some years ago with the method of naturalistic observation, we presently standardized roughly the conditions under which consorts were brought together in controlled matings, and, in every such experiment, briefly described what appeared to be the sexually significant features of behavior. The question which we initially sought to answer was: Does oestrus occur in this primate? Our results established the affirmative. They have already been reported in part, together with description of typical mating behavior and discussion of factors which affect it (Yerkes and Elder, 1936). Knowledge of the content of the previous publication will hereafter be assumed, as it is essential to a proper understanding of the present report.

Analysis of the data gathered by Yerkes and Elder in between five and six hundred mating experiments, and attempts to describe the variations and relations of sexual responsiveness in the chimpanzee, revealed

YALE LABORATORIES OF PRIMATE BIOLOGY

CONTROLLED MATING RECORD

Female ..Nana.. Male ..Bokar.. Observer ..R.M.Y.....
Cycle day ..20.. Sexual status of F ..Max.. Date ..June 8, 1937, 10.14 a.m.
Prior cage and company of F ..Quarters 8, with May.. of M ..Quarters 5.....
Mating location of F ..Quarters 5.. of M ..Quarters 5.....
Initiative: F to M ..✓.. M to F .... Exchange .... No change .....
Presentation of F: Low ..✓.. High .... Intermediate .... Erect .... Other .....
Initial response of M: To female .... Waiting ..✓.....
Genital gesture ..✓ ✓.. Hand gesture .... Slapping ground .....

MINUTES		1	2	3	4	5	6-10
F presentations		✓	✓				
M approaches			✓	✓			
Erection		✓	✓	✓			
Covering:	Time	7"	10"				
	Thrusts	14	21				
Ejaculation		✓	✓				
Genital exam.:	F by M						
	M by F						
Grooming:	F by M			✓	✓	✓	
	M by F						
Indifference:	F						
	M						

Behavioral Ratings, on a scale of 0 to 4 (To be made on the spot)

	Pre*		Post*			Post*
Receptivity of F	4	(0–4)	4	Dominance–subm. of F	(+4 to –4)	–1
Desire of M	4	(0–4)	4	Dominance–subm. of M	(+4 to –4)	0
Acceptability of F		(0–4)	4	Timidity of F	(0–4)	0
Acceptability of M		(0–4)	4	Aggressiveness of M	(0–4)	0

Mating prediction: Yes ..✓.. No .....
Mating pattern: Complete ..✓ ✓.. Incomplete .... Typical .... Atypical .....

Notes: **From first copulation F rushed away screaming, but in the second she held her position until the male withdrew. He eagerly groomed her after the second copulation, which evidently satisfied him.**

* Referring to removal of barrier between cages.

FIG. A. FACSIMILE OF MATING RECORD

informational deficiencies which clearly were chargeable to the inexperience of the observers and the inadequacy of their methods. The desirability of continuing the investigation with increasingly satisfactory procedures was obvious. As a possible step forward, a rating scale to cover various aspects of responsiveness was incorporated in the revision of our original record form. This methodological device, with its provision for the systematic rating of certain forms of behavior, assures more inclusive, significant, and reliable description of behavior than had previously been attained.

The reader's attention is invited to the sample completed record which is reproduced in Fig. A. In describing its content, pains will be taken to exhibit especially those items and aspects of behavior which have been found to be indicative of sexual status and serviceable as measures of responsiveness in male, female, or both.

The first four lines of the blank are to be filled appropriately before the consorts are permitted to come together. So, likewise, the pre-mating rating of "receptivity of F" (female), "desire of M" (male),[2] and the "mating prediction" as yes or no, which are provided for near the bottom of the blank.

The mating situation in its essentials involves the presence of consorts in adjoining cages, separated by a wire mesh partition, with a sliding door. When the door is opened for an experimental mating the observer notes and immediately records the following forms and features of behavior whose sexual relevancy has been revealed by previous observation.

(1) Under "initiative," the first locomotor response after removal of the barrier between the consorts is recorded as F to M, that is, F entering the cage of M; M to F; exchange of cages; or no change. This response, like various others which were recorded, in a given instance may or may not be sexually motivated.

(2) The specific response of the female to the male when they come together is provided for under the caption "presentation of F," because of our discovery that the manner as well as the fact of presentation is of prime importance as indicator of degree of receptivity. Generally speaking, low presentation, in which the female prostrates herself before the male, indicates a high degree of receptivity, whereas the "erect"

[2] If we were now selecting our terms, we should use "responsiveness" instead of "desire" in this connection.

posture implies either lack of it or unwillingness to accept a particular male.

(3) Almost as valuable an indicator as presentational behavior or its absence is the "initial response of M" to F. If he simply ignores her, it ordinarily is either because she is non-receptive or for some other reason unacceptable to him; if he approaches and examines her, the possibilities are varied and judgment concerning receptivity must remain temporarily in abeyance; if he assumes copulatory posture ("waiting") and awaits her approach and presentation, expectancy of sexual union is indicated and the probability is high that the female is in receptive phase. When under such circumstances F responds slowly or refuses to approach and present, M may solicit her coöperation by gestures whose meaning is unmistakable. Most frequently observed are the following types of solicitational behavior: the "genital gesture" of exhibitionism; the "hand gesture" of appeal; or, instead of such gestures of request, the male may slap or stamp the ground or floor in a gesture of command.

(4) Within the ruled area, the blank provides for the entry, minute by minute, throughout the five-minute duration of an experiment[3] of the following items: number and distribution of female presentations; male approaches to the female; erections; copulations (with record of duration and pelvic thrusts); genital examinations; grooming; and indifference behavior. As will appear from our later analysis and discussion, these various items may have other social significance than the sexual or they may be important features of the mating pattern.[4]

Behavioral ratings, based upon the total picture presented to the observer in the course of an experimental mating, only the most important features of which could be recorded, are provided for at the bottom of the blank. The rating scale used consists of five steps, 0 to 4, except that for dominance-subordination a nine-step scale, extending from +4 to —4, was used. Numerical values were not assigned to behavioral items, since it seemed safer, in the present status of knowledge

[3] Whereas when we began to explore the possibilities of studying mating behavior experimentally, observation was continued for one hour, the period shortly was reduced to 30 minutes because of the rapid diminution of observational return. Later it was lessened to 15 minutes; and finally, for all matings made to measure receptivity, the interval was fixed at 5 minutes. Usually a male was used for only one mating per day in which copulation occurred.

[4] For description of the typical mating behavior of chimpanzees under the conditions of this investigation, see Yerkes and Elder (1936, pp. 7-10).

and experience, to try to appraise and evaluate the total behavioral picture than arbitrarily to assign values to items whose importance might vary extremely from one experiment to another.

This is a crude procedure which as soon as feasible should be improved upon or supplanted. We are aware that in these experiments receptivity is influenced by two major groups of factors, the male and the female. Obviously until the male factors can be eliminated or held constant, reliable and safely interpretable measurement of female receptivity is impossible. It is necessary to discover a satisfactory method of measurement of female status and receptivity when the male is represented by some constant symbol or other controllable experimental convention.

All rating judgments, with the exception of those mentioned previously as pre-ratings and predictions, are made by the experimenter immediately upon the completion of observation. The four ratings in the left column represent aspects of sexual responsiveness exhibited in the mating situation. Naturally the receptivity of the female must be distinguished from the desire, or, better, responsiveness of the male, and these in turn from the sexual acceptability of each consort for the other. The right column offers place for measures of the dominance or subordination of each consort, the timidity of the female, and the aggressiveness of the male, any or all of which may function importantly in the mating experiment.

Whereas in our previously reported study of oestrus, copulatory behavior was accepted as index of receptivity and no attempt was systematically made to measure the strength of sexual responsiveness, the present report offers observational data and ratings based upon them which enable us to approximate quantitative description.

There follows a list of the behavioral items upon which we chiefly depended in formulating rating judgments. They are: (a) The willingness or eagerness of F to go to M initially and to remain with him or have him accompany her to her cage after the experiment; (b) the willingness or eagerness of F to approach M and to offer herself for sexual examination, copulation, or grooming; (c) the manner and frequency of presentation by F to M; (d) in the event of presentation and covering, the attitude, vocalization, duration of passivity, and the nature and degree of coöperation of F in sexual union; (e) efforts of F to attract the attention of the non- or slightly responsive male by posture, gesture, direction of movement, vocalization, and playful antics,

all of which may be forms of female solicitation; (f) behavioral evidences of F's consciousness of, and interest in, M, whether or not he be at hand and visible; (g) anticipatory behavior while preparations for a mating experiment are in progress. These may include excited rushing about the cage and varied evidences of preparedness to run to the male or to avoid him when he becomes accessible.

Under the conditions which have been described in detail elsewhere (Yerkes and Elder, 1936, p. 5) and by use of the observational rating procedures outlined above, a total of 233 experimental matings were observed in the Southern Division of Yale Laboratories of Primate Biology from May to August, 1937. The nine chimpanzees, six females and three males, listed with essential descriptive data in Table 1, served as subjects. In order to minimize the risk of undesired pregnancies during the investigation, one of the males, Pan, was vasectomized. So far as practicable, matings were made with a given pair of consorts at regular intervals throughout a sexual cycle. The sterile male, whenever possible, was used protectively at the time of expected ovulation.

TABLE 1

List of chimpanzee subjects

NAME AND NUMBER	SEX	BIRTH-DATE	SEXUAL STATUS	REPRODUCTIVE HISTORY*	
				Births	Miscarriages
Cuba (46)	F	Mar. 24, 1926**	Mature	1	0
Josie (30)	F	1922	Mature	2	1
Mamo (18)	F	July, 1928	Recently mature†	0	0
Mimi (44)	F	1923	Mature	0	1
Nana (6)	F	1921	Mature	2	2
Wendy (4)	F	1923	Mature	2	0
Bokar (5)	M	1925	Mature	..	..
Jack (17)	M	1920	Mature	..	..
Pan †† (3)	M	1922	Mature	..	..

* As of May 1, 1937.

** Actual birth-date. All other dates are hypothetical.

† First menstruation, Aug. 14, 1936.

†† Vasectomized April 13, 1937.

To understand what follows it is essential that the reader have in mind the macroscopically distinguishable phases of the chimpanzee sexual cycle.[5] From the beginning of one period of menstrual bleeding to the next, the modal interval is 35 days. The cycle presents six phases which are distinguishable by the presence or absence of bleeding and genital swelling. The latter may reach extraordinarily large proportions in this primate.

III. OBSERVATIONAL DATA FOR INDIVIDUAL SEXUAL CYCLES

The results of our experiments will now be presented in graph, table, and discussion. It is intended, by the method chosen, to exhibit typical results and variations of receptivity and responsiveness which are associated with individual characteristics, degree of normality, reproductive status, and the affective characteristics and relations of consorts.

The accompanying Figs. 1 to 5 represent relations of responsiveness ratings and mating results to cycle phase. In the several figures the cycle days are numbered from the beginning of menstrual bleeding. The six phases are designated: menstrual (M), postmenstrual (Post), tumescent (+), maximal swelling (Max), detumescent (—), premenstrual (Pre). The upper solid-line curve of the figures indicates variations in sexual swelling, zero swelling being represented on the base line, and the maximum at the apex of the curve. The broken-line curve is plotted from measurements of female receptivity. On this curve the several matings are indicated by symbols which designate also the male used for the mating: Bokar, ○; Jack, ⊙; Pan, ×. The results of matings are indicated by the symbol "+" if resulting in copulation, or the symbol "—" if not.

Observational data for two cycles of the normal female Nana are represented in Fig. 1. The data for cycle A are taken from our current series of experiments; those for cycle B, from an earlier period of this investigation. For cycle A the duration of maximal receptivity was relatively long; for cycle B, short. Differences in cycle phases between A and B are not exceptional and require no comment. The opposite is the case for receptivity ratings and mating responses, since the differences are extreme. That they depend upon the variations in the sexual condition of the female seems improbable, in the light of complete informa-

[5] Descriptions of the sexual and reproductive cycles of the chimpanzee have been presented by Zuckerman (1930), Tinklepaugh (1933), Elder and Yerkes (1936), and Yerkes and Elder (1936, 1937).

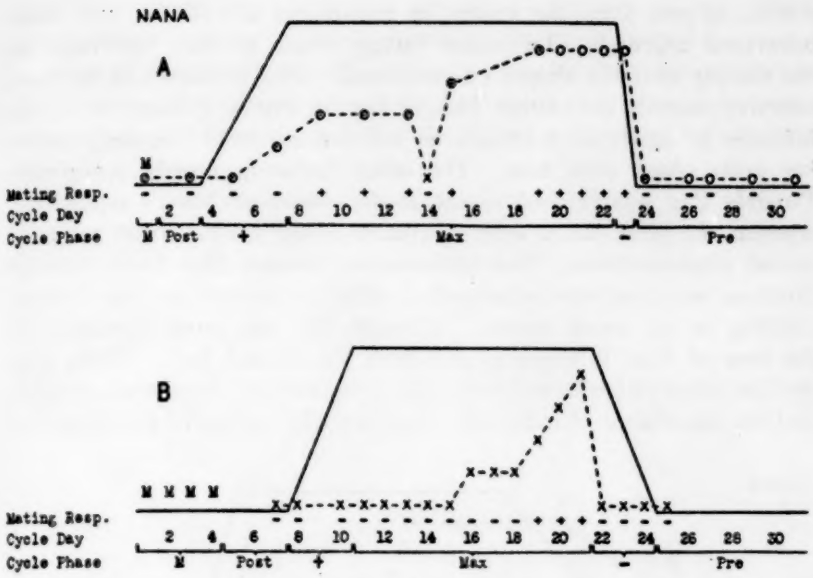
NANA
A
M
Mating Resp.
Cycle Day
Cycle Phase
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
M Post + Max - Pre
B
M M M M
Mating Resp.
Cycle Day
Cycle Phase
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
M Post + Max - Pre

FIG. 1. REPRESENTATION OF FEATURES OF TWO SEXUAL CYCLES, SUBJECT NANA, TO PRESENT IN THEIR TEMPORAL RELATIONS MACROSCOPIC PHASES OF THE SEXUAL CYCLE, BLEEDING (M), GENITAL SWELLING (——), SEXUAL RECEPTIVITY RATINGS (- - -), AND MATING RESPONSES

A. Data for relatively long cycle (May 20, 1937, and continuing into pregnancy). B. Similar data for relatively short swelling cycle (June 4, 1935.)

tion concerning the individual. It is more probable that they should be attributed to the male consort. This is enhanced by the fact that different individuals were used as consorts. For cycle B, Pan was used throughout; for cycle A, he was used only once (14th day), and in that case with negative result. Jack was used from the 1st to the 19th day of cycle A, with the above noted exception, and Bokar from the 20th to the 31st, with the exception of the 24th day. As we evaluate them, the results for A and B represent markedly different degrees of male sexual dominance. It is doubted that, apart from the influence of the male, the sexual responsiveness curves would have differed greatly.

Nana had lived familially with Pan for many months, was on terms of friendly intimacy, and he was obviously fond of her. She was acquainted with both Jack and Bokar, although not intimate with either. As she trusted neither of them to be as gentle and considerate of her

desires as was Pan, she tended to respond in accordance with their behavioral approach. Two other factors which possibly functioned in the mating situation should be mentioned. Pan is known to be more selective sexually than either Jack or Bokar; that is, irrespective of the behavior or desire of a female, he will not accept her sexually unless her cycle phase suits him. The other factor is female preference. Possibly Pan was refused except at the climax of Nana's receptivity, whereas the other males were acceptable to her over a wider range of sexual responsiveness. Our observations indicate that Nana differed from our other subjects in her greater ability to control the male without yielding to his sexual desire. Although this was most impressive in the case of Pan, it appeared also with Bokar and Jack. These suggestions serve rather to emphasize the complexity of the mating situation and the importance of individual characteristics and social relations than

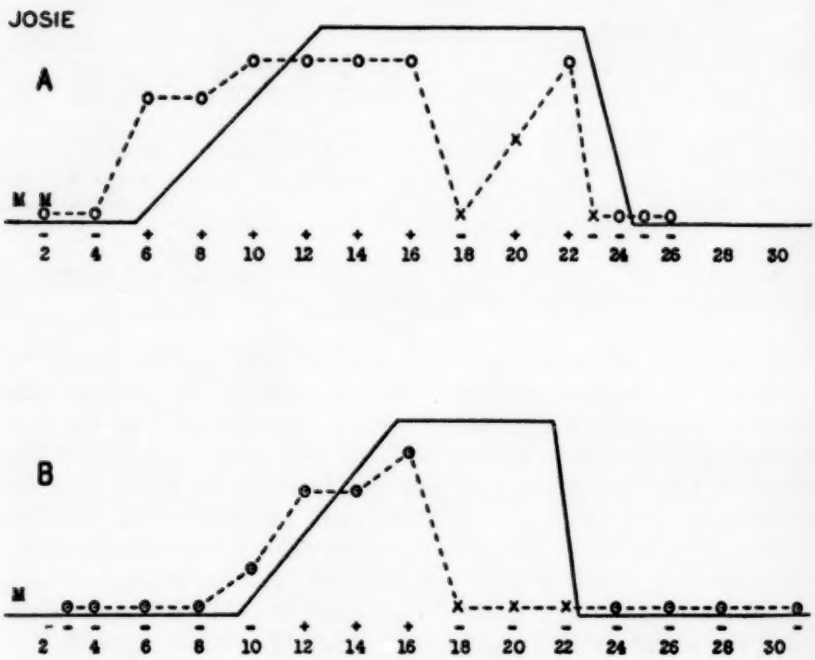

FIG. 2. SEXUAL CYCLE CURVES OF FEMALE

A. Data for a 36-day cycle (May 7 to June 11, 1937) of subject Josie. B. Data for indeterminate cycle beginning June 12, 1937.

to settle the question: Why was maximal receptivity of very short duration in cycle B and of relatively long duration in cycle A?

Especially to exhibit individual differences in the form and variations of receptivity, there have been juxtaposed in Figs. 2 and 3, for comparison with Fig. 1, cycle graphs for the typical and normal female Josie

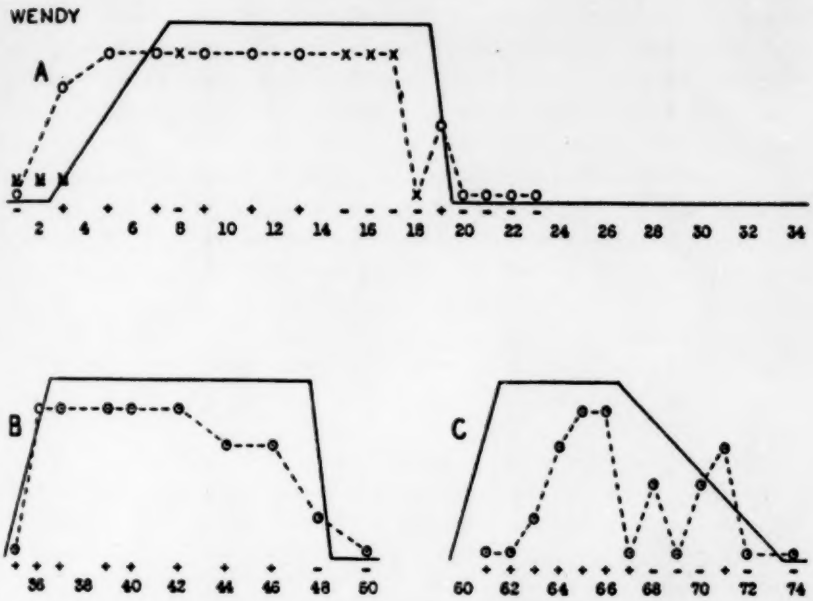

FIG. 3. SEXUAL CYCLE CURVES OF FEMALE

A. Data for normal cycle of subject Wendy which began May 7, 1937. Conception occurred during this cycle. B. First pregnancy swelling cycle. As menstruation did not occur following the previous cycle, the days of this swelling cycle are numbered continuously with those of A. C. Second pregnancy swelling cycle. It is to be noted that menstruation did not occur between cycles B and C.

and for the very highly responsive individual Wendy, whose behavior at times suggests nymphomania. As during Wendy's cycle A fertilization occurred, contrary to the intention of the experimenter, it is possible to present also graphs for the first and second non-menstrual genital swellings which occurred during pregnancy, and for the sexual responses which were observed. At this point discussion will be limited to the non-pregnant cycle (Fig. 3A).

The vasectomized male Pan, with a single exception on the part of Josie (cycle A), was refused by both Josie and Wendy. Consequently receptivity ratings are lacking and mating responses negative for experiments in which Pan was used. However, if for the days on which he served we substitute the pre-mating responsiveness ratings for the mating receptivity ratings, it appears that Josie's sexual receptivity continued at maximum (rating 4) from the 10th to the 22d or 23d day in cycle A, and from the 16th to the 21st or 22d days in cycle B. It is noteworthy that for A, Bokar usually was the consort, and for B, Jack. The former more strongly appealed to Josie than the latter and evoked greater sexual response.

By contrast with Josie, Wendy in cycle A exhibited maximal receptivity relatively early and continuing from the 5th to the 17th or 18th day. She was fertilized by Bokar either on the 13th or the 19th day, presumably the former, and her atypical behavior and the resulting sexual ratings which were obtained for the 18th and 19th days may be due to gestational processes, or to the change of mate from Pan to Bokar. Ordinarily receptivity would have been maximal on the former day, zero on the latter, and the mating responses would have been reversed.

Absolute measurements of sexual receptivity, were they available, undoubtedly would be much greater for Wendy than for Josie, as she responded more promptly, vigorously, persistently, and frequently to the male. This does not appear in the ratings because the value "4" represents an individual maximum.

The generalization suggested by the data of Figs. 2 and 3 is that a high degree of sexual receptivity is coextensive with the phase of maximal genital swelling. This, however, is not supported by our results for Nana, Fig. 1, and it is presented here with the reservation that it may prove to be invalid for the species under natural versus experimental conditions of mating. We have varied behavioral evidence that the climax of receptivity is achieved, and continues at most for a few days, during the latter half of the period of maximal swelling.

Results for the recently matured female Mamo are offered in Fig. 4 in contrast with those presented above for the fully matured and reproductively experienced individuals Nana, Josie, and Wendy. Mamo first menstruated in August, 1936, but no pregnancy had been observed and it is not certain that ovulation had occurred prior to these experiments.

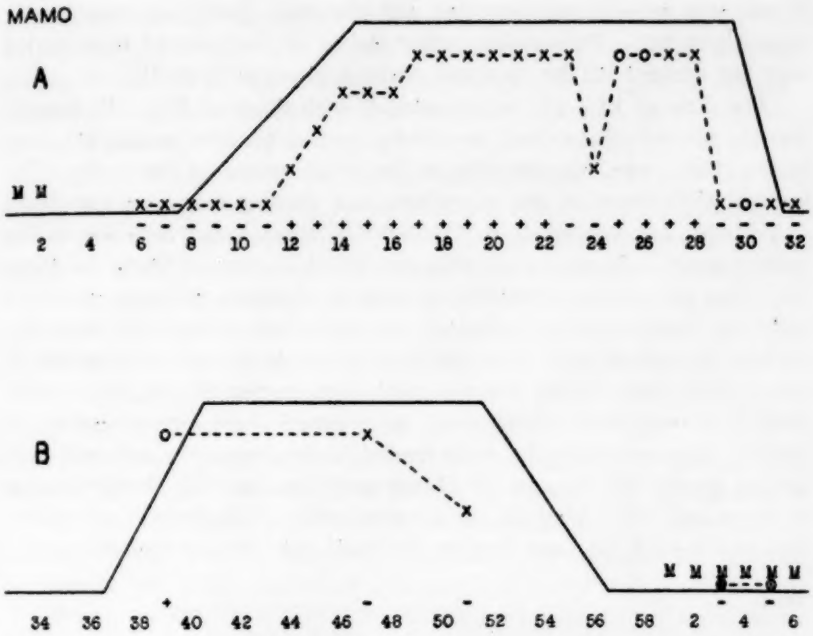

FIG. 4. SEXUAL CYCLE CURVES OF A RECENTLY MATURED FEMALE

A. Cycle beginning April 30, 1937, of the recently matured female Mamo. B. As the previous cycle was not terminated by menstrual bleeding, the numbering of days for this cycle is continuous with that of cycle A.

Pan served as consort of Mamo for cycle A, except as Bokar was used to check unexpected results, as on days 25 and 30, following refusal of the female by Pan. From cycle days 1 to 11 Mamo was non-receptive; between days 12 and 17 receptivity gradually increased to a maximum which continued until day 28, whereupon it abruptly dropped to zero.

Menstruation was not observed after the swelling of cycle A; instead, six days after the completion of detumescence the genital area began to swell. In this atypical non-menstrual cycle (B), Mamo responded with maximal receptivity to the male Bokar on the 39th day and was accepted by him, while on the 47th day her like response to Pan was met by his refusal to mate. Detumescence in cycle B was unusually gradual, and it was followed promptly by menstruation. During the menstrual condition and the postmenstrual phase of the next cycle,

Mamo was wholly non-receptive and the male Jack was consistently negative to her. Presumably either Bokar or Jack would have mated with her throughout the maximal swelling phase of cycle B.

The data of Fig. 4A, in comparison with those of Fig. 1B, suggest that the brevity of maximal receptivity, and of positive mating response in the latter case, was not due to the selectiveness of the male. The marked differences in the receptivity and mating responses for Nana and Mamo are intelligible in the light of their social relations to the male consort. Nana, as experienced breeder, was perfectly at home with Pan and easily controlled the mating situation, whereas Mamo, a relatively inexperienced individual, reproductively considered, was only slightly acquainted with him, timid in his presence, and mistrustful of him. Nana took varied liberties with him during the mating experiments; Mamo never dared even to approach him for grooming or petting. Consequently the male tended to determine the outcome of a mating experiment in case of Mamo and Pan, and the female in case of Nana and Pan. Had the social relationship of dominance-subordination and confidence been similar for each pair, the receptivity ratings

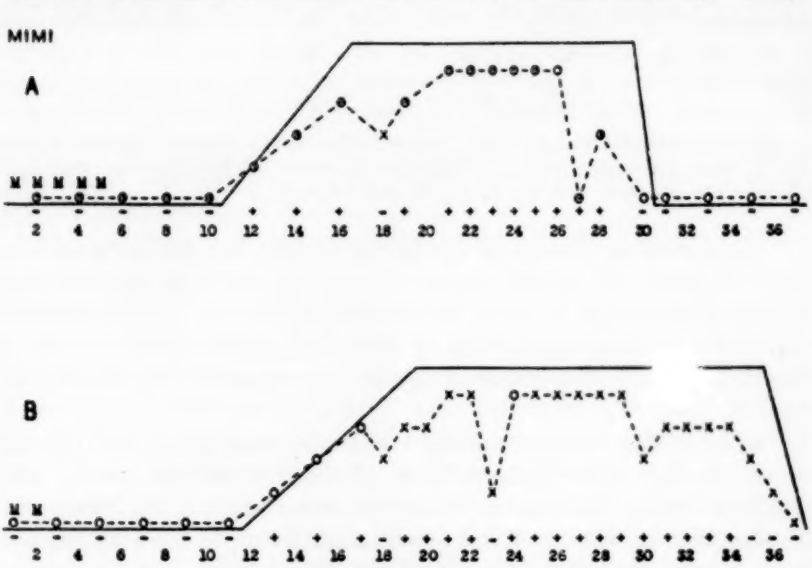

FIG. 5. SEXUAL CYCLE CURVES OF AN ABNORMAL FEMALE

A. Data for a 40-day cycle (May 16 to June 24, 1937) of the abnormal female Mimi. B. Data for the following, a 45-day cycle, of the same subject.

and mating responses probably would have differed inconsiderably. One may infer from these and similar observations that the less the subordination of F to M, the more restricted the period of maximal receptivity and of acceptability of the consorts to one another, ***as measured in these experiments.***

Finally, as variation from the normal, the data of Fig. 5 are presented for the behaviorally atypical, and in certain respects pathological, subject Mimi. For several months during the calendar year 1937 this subject exhibited marked lassitude, occasional choreiform movements, and other signs of nervous disturbance. Her sexual and reproductive history is unusual, for although menstruation began in July, 1932, and since that time she has been mated repeatedly, only one pregnancy has been observed, and it terminated in miscarriage at six months. Possibly because of her unusual neural and glandular status, Mimi exhibits a low level of sexual responsiveness. It is doubtful that, at maximum, it is more than half the strength of Wendy's. In the mating experiment her interest, eagerness, and coöperativeness are relatively poor, and even when fully receptive she habitually presents in an intermediate position, awkwardly and to the disadvantage of the male.

Worthy of remark in Fig. 5 are the following points. Sexual receptivity is zero and mating response negative during the menstrual, post- and premenstrual cycle phases; positive results appear in the early stages of tumescence, and receptivity gradually waxes alike in cycles A and B from about the 10th to the 21st days. Maximal receptivity ratings were assigned for six to ten days, whereas with the onset of detumescence the sexual responsiveness of the female disappears completely. Roughly, then, Mimi may be described as more or less receptive, or at least sexually accommodating, during approximately half of her cycle. Hers is a case in which the curve of receptivity change is coextensive with, and in general markedly resembles, that of genital swelling.

The following observation is of peculiar interest. Mimi, on the 26th and again on the 27th days of cycle B, was reluctant to leave the cage of Pan to return alone to her own. Previously she had been entirely indifferent, and when on the completion of an experiment the door between the cages was opened she returned promptly, and often with evident eagerness. So markedly at variance was her behavior on these dates with that both earlier and later that it suggested significant increase of sexual desire and the possibility of relationship between the behavior and the time of ovulation. It is possible that maximal recep-

tivity rating should have been assigned only on days 26 and 27. Evidently our rating procedure, as used for these observations, is too crude to reveal variations from the maximum when all behavioral signs are more or less positive and there is no single item which can be relied upon as decisive.

Demanding explanation is the fact that the curve of receptivity, as plotted in Figs. 1 to 5, rises gradually during the tumescent or maximal swelling phases, finally reaches its maximum, and so continues for a varying interval, whereupon it drops abruptly to zero. Why the gradual waxing and the sudden waning? The following possibilities occur to us. The hormonal factors which control oestrus may become effective gradually upon the appearance of tumescence, and/or the influence of the male consort upon the responsiveness of the female may steadily increase as genital swelling progresses and the moment of ovulation is approached. Either of these hypotheses would account for the facts. The sudden waning of receptivity we may assume to be due to the physiological state induced by ovulation.

It remains to discover, by appropriate experiments, whether the typical curve of receptivity is that of Fig. 1B or of Fig. 2A — whether maximal receptivity is prolonged or brief. Our evidence at present points clearly to the latter in those matings in which F tends to control the situation, and to the former in those in which M dominates.

IV. FACTORS AND RELATIONS IN SEXUAL RESPONSIVENESS

In the hope of discovering and evaluating psychobiological factors which may affect or determine sexual responsiveness and mating, we shall now examine significant items and aspects of response in their relations to the total experimental situation. Naturally, choice will be restricted to those items which find place in our record form and rating scale, since for them we have relatively comparable data from experiment to experiment as well as among individuals.[6]

What do the data reveal concerning relations of receptivity, desire, and acceptability ratings to cycle phase, and, in particular, to genital swelling? The question is of special importance because of the surmise, on fragmentary evidence, that primates which exhibit genital swelling may copulate throughout the period of swelling. Is this true for the chimpanzee? Our principal relevant data appear in Table 2, where the

[6] A tentative factor-analysis appears in Yerkes and Elder (1936, p. 28).

TABLE 2

Relation of sexual responsiveness and acceptability ratings to cycle-phase and frequency of copulation

MEASUREMENTS	CYCLE PHASES					
	Menstrual	Postmenstrual	Tumescent	Maximal swelling	Detumescent	Premenstrual
Receptivity of F	0	0	1.88	3.01	0.74	0
Desire of M	0.44	0.17	2.82	3.54	1.91	0.48
Acceptability of F	0	0.03	2.29	3.18	0.91	0
Acceptability of M	0	0.03	1.82	2.63	0.61	0
No. of observations	9	30	34	89	23	48
Frequency of copulation (complete cases only)	0	0	21 (23.6%)	65 (73%)	3 (3.4%)	0

average rating values for all experimental matings (233) have been arranged by cycle phase.

From this statistical array it appears that the female is non-receptive except during the swelling phases of the cycle, whereas the measurements of male desire reflect the influence of the female's sexual status, being lowest during the menstrual and adjacent cycle phases. Copulation, in completed typical form, occurs only during the swelling phases, and with highest frequency during maximal swelling. Peculiarly significant is the recent discovery of Elder (1938) that fertile matings occur only during the last few days of maximal swelling. Presumably ovulation is limited to this period.

Partial answer to the question, what relation does sexual responsiveness bear to acceptability, may be discovered in Table 3, where for ready comparison we have arranged the rating averages for 104 experimental matings in which F was covered by M with or without completion of the mating pattern. Individual differences among pairs of consorts are conspicuous, and the reliability of averages is low because of the fewness of observations. Coefficients of correlation therefore have not been determined.

TABLE 3

Sexual receptivity (or desire) and acceptability ratings for the several pairs of consorts in copulatory matings

	BOKAR					JACK					PAN					TOTAL OBS.
	R of F	D of M	Ac. of F	Ac. of M	No. obs.	R of F	D of M	Ac. of F	Ac. of M	No. obs.	R of F	D of M	Ac. of F	Ac. of M	No. obs.	
Cuba	3.00	4.00	3.00	3.00	1	1.00	3.00	1.00	0	1	2.00	2.75	1.00	2.25	4	6
Josie	3.71	3.86	3.71	3.71	7	3.33	4.00	3.67	3.33	3	0.33	4.00	4.00	0	6	16
Mamo	4.00	4.00	4.00	4.00	3	...	...	...	...	..	3.43	3.21	3.14	3.43	14	17
Mimi	2.67	4.00	2.83	2.33	6	3.10	3.90	3.50	2.90	10	3.27	3.82	3.55	2.82	11	27
Nana	4.00	4.00	4.00	4.00	4	2.60	4.00	3.60	2.60	5	2.00	3.00	3.50	2.00	2	11
Wendy	3.67	3.78	3.67	3.67	9	2.57	3.79	3.50	2.64	14	4.00	4.00	3.00	0	4	27
Gen. avs.	3.51	3.94	3.54	3.45	30	2.52	3.74	3.05	2.29	33	2.51	3.46	3.03	1.75	41	104

TABLE 4

Relation of behavioral initiative in mating to phases of the sexual cycle

RESPONSES OF MATES	CYCLE PHASES						TOTAL
	Menstrual	Post-menstrual	Tumescent	Maximal swelling	De-tumescent	Pre-menstrual	
F to M	1 (11%)	11 (37%)	22 (65%)	74 (83%)	13*(59%)	18 (37%)	139
M to F	8 (89%)	15 (50%)	11 (32%)	14 (16%)	8 (36%)	23 (48%)	79
Exchange	0 (0%)	3 (10%)	1 (3%)	0 (0%)	1 (5%)	7 (15%)	12
No change	0 (0%)	1 (3%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	2
Total observations	9	30	34	89	22	48	232

* One mating omitted because of incompleteness of record.

In general, the acceptability of F to M varies directly with receptivity. And whereas, according to the averages, female acceptability does not vary greatly for the several males, the acceptability of the male to the female ranges from 1.75 for Pan to 2.29 for Jack and 3.45 for Bokar.

In this connection again we must regard the fact, in evaluating results, that receptivity and desire are interdependent and that in consequence neither represents the strength of sexual responsiveness of the one consort independent of the other. Similarly, acceptability is a social relationship rating, to which each consort necessarily contributes.

The positive correlation of initial movement of the consorts in the mating experiment with responsiveness and copulation is exhibited by the data of Table 4. According to the statistical values, F responds by going to M most frequently (83 per cent) during the maximal swelling phase, when receptivity is highest and copulation most probable; whereas M goes to F most frequently (89 per cent) during the menstrual phase, when F is non-receptive and copulation exceptional. Evidently the tendency of M to enter the cage of F at the beginning of an experiment varies inversely with her degree of receptivity. The results confirm our previous observations and conclusions (Yerkes and Elder, 1936, pp. 23 ff.).

Comparable in importance with the initial locomotor response considered above is the initial phase of the male's response to the female in the mating experiment. Pertinent observations have been classified in Table 5 for the several females by receptivity rating categories, 0 to 4, and also by the male response categories: movement of male to or toward female (to F); waiting of male in copulatory posture (W); and indifference or unresponsiveness of male (I).

From the materials of Table 5 these generalizations may be read. It is noteworthy that they confirm those suggested by the content of Table 4. The male goes to the female most frequently when her receptivity is low. He most frequently awaits her in copulatory posture when it is high. When the receptivity ratings are 3 or 4 the male rarely exhibits indifference or ignores the female sexually; when the rating is 0, sexual indifference is the rule.

Solicitation of F by M varies extremely in form and frequency with individual males and the mating situation. The higher the receptivity rating, the more likely is M to solicit F, gesturally or posturally, in case she does not come to him promptly and present sexually.

TABLE 5

Relation of initial mating response of the male to the sexual receptivity rating for the female

RECEPTIVITY RATING	0			1			2			3			4			NO. OBS.
RESPONSE OF M	To F	W	I	To F	W	I	To F	W	I	To F	W	I	To F	W	I	
Cuba	2	3	..	..	1	..	..	1	..	..	3	..	..	..	..	10
Josie	8	4	10	1	..	..	1	..	..	..	4	..	..	6	..	34
Mamo	4	5	18	..	1	1	1	1	..	..	3	..	..	12	1	47
Mimi	7	1	14	2	2	..	5	2	1	2	8	..	1	13	..	58
Nana	11	2	15	..	2	..	..	3	..	..	2	..	..	5	..	40
Wendy	9	2	6	2	..	..	1	1	1	1	4	..	2	15	..	44
Total observations	41	17	63	5	6	1	8	8	2	3	24	..	3	51	1	233
Percentages	34	14	52	42	50	8	44	44	11	11	89	..	5	93	2	...

TABLE 6

Relation of type of female sexual presentation to cycle phase and copulation

RESPONSE	CYCLE PHASES						TOTALS	COPULATIONS*
	Menstrual	Post-menstrual	Tumescent	Maximal swelling	De-tumescent	Pre-menstrual		
None	7 (78%)	28 (93%)	7 (21%)	9 (10%)	12 (52%)	40 (83%)	103	6 (6%)
High	0 (0%)	1 (3%)	5 (15%)	9 (10%)	4 (17%)	2 (4%)	21	9 (43%)
Intermed.	1 (11%)	1 (3%)	8 (24%)	45 (51%)	3 (13%)	3 (6%)	61	50 (82%)
Low	1 (11%)	0 (0%)	14 (41%)	26 (29%)	4 (17%)	3 (6%)	48	40 (83%)
Totals	9	30	34	89	23	48	233	105

* Coverings, either with or without ejaculation.

Among several features of mating behavior which almost always have sexual significance, probably none is so reliably indicative of receptivity and preparedness to mate as the fact and form of female presentation. Our relevant observations have been arranged in Table 6 by type of presentational response (none, high, intermediate, low, terms which refer to the relation of the posturing animal to the ground) and cycle phases. Frequency of copulation for each type of presentational response is given in the last column of the table. In the absence of presentation (none), copulation is exceptional (6 per cent); high presentation by the typical female is indicative of a low degree of receptivity or its absence and of unwillingness to mate (43 per cent);[7] intermediate and low presentations, depending upon the individual, are indicative of high receptivity and presage copulation.

Individual females have characteristic modes of sexual presentation. Thus that of Cuba, during maximal receptivity, is low or intermediate; of Josie, consistently low; of Wendy, also consistently low; of Nana, either intermediate or low; of Mamo, low or intermediate; and of Mimi, intermediate or high. For all individuals, without exception, the greater the strength of receptivity and the more acceptable (preferred or liked) the expected male consort, the more probable is low presentation.

Typically then, and apart from idiosyncrasies or abnormalities, the female may be expected to refuse to present if non-receptive; to present for examination if only slightly receptive; and to offer herself in intermediate or low position if fully receptive and expectant of sexual union. When the female presents in low or prostrate posture, she commonly thrusts herself before or against the male in copulatory attitude and with evident expectation of being accepted. If refused by the male, she may actively resent the behavior of her consort with expressions of disappointment and anger. Repetition of presentation low during the five-minute interval of the experiment is indicative of a high degree of receptivity, and presumably in many instances of its climax.

V. THE RÔLE OF THE MALE

Already it has been intimated, and we shall now attempt to prove, that it is worse than futile to predict the outcome of a mating experiment

[7] Very significant is the fact that the statistical value 43 per cent becomes 19 per cent if the observations for the atypical, and presumably at times abnormal, female Mimi be omitted. Mimi characteristically, and almost without exception, presented in intermediate or high posture.

or to try to describe the resultant behavior without taking into account the physical and psychobiological characteristics of each of the consorts and such social relations between them as are exemplified by our measures of dominance-subordination, timidity, and aggressiveness.

In order to exhibit relations between physical and behavioral traits of our male subjects and their sexual acceptability to the females, we have ranked the males in order from greatest to least value with respect to seventeen traits. The results appear in Table 7. Whenever numerical values are available they have been included.

TABLE 7

Rank-order, from greatest to least values, of various features of physique and behavior in the males

CHARACTERISTICS	MALES		
Age in years*	Jack (17 yrs.)	Pan (15 yrs.)	Bokar (12 yrs.)
Vigor — physical and sexual	Bokar	Jack	Pan
Length of penis	Bokar	Pan	Jack
Amount of sexual experience	Pan	Bokar	Jack
Duration of copulation	Bokar (9.8″)	Pan (8.0″)	Jack (6.7″)
Number of copulatory thrusts	Bokar (19.7)	Pan (19.1)	Jack (12.4)
Degree of sexual selectiveness	Pan	Jack	Bokar
Gestural solicitation by M	Pan	Jack	Bokar
Dominance-subordination	Pan (.80)	Jack (.76)	Bokar (.71)
Aggressiveness	Jack (.59)	Pan (.43)	Bokar (.27)
Grooming:			
F by M	Pan (18-30′)	Bokar (10-22′)	Jack (3-4′)
M by F	Bokar (25-68′)	Jack (18-52′)	Pan (6-15′)
Predictability of copulation	Bokar (94.5%)	Jack (89.0%)	Pan (72.9%)
Sexual responsiveness:			
Desire of M	Bokar (3.94)	Jack (3.74)	Pan (3.46)
Acceptability of F	Bokar (3.54)	Jack (3.05)	Pan (3.03)
Acceptability of M	Bokar (3.45)	Jack (2.29)	Pan (1.75)
Intelligence	Bokar	Jack	Pan

* Estimated as of Jan. 1, 1937.

Age, physical and sexual vigor, penis length, and intelligence were estimated from reasonably adequate observational data. The relationships exhibited by the table, in conjunction with details of observation which we may not presume to report, strongly support the generaliza-

tion that the sexual acceptability of M to F tends to vary directly with vigor, penis length, and copulational time and thrusts, and inversely with degree of sexual selectiveness, dominance, and aggressiveness. From our observations it appears that female preference in mates is dependent largely upon the physique and sexual behavior of the male. Probably this is not an adequately inclusive statement, for without doubt factors of habituation and social congeniality are significant, and may on occasion determine the attitude of F to M.

As to the copulatory behavior of the consorts, the two measures provided — duration and number of pelvic thrusts — are affected by both consorts, since the female may at any moment terminate the union by rushing away and the male by withdrawing. As a fact, in many instances, unless she is fully receptive and confronted by a preferred and congenial male, the female terminates a copulatory mating in 5 to 8 seconds. Her attitude toward M and her degree of satisfaction in the copulatory act, together with the degree of male dominance, presumably determine the duration of female coöperation. On account of these facts the statistical data for measurements of copulation are presented for each male separately and also for each pair of consorts in Table 8.

TABLE 8

Measurements of copulatory behavior

FEMALE	BOKAR			JACK			PAN		
	Time	No. of thrusts	No. of obs.	Time	No. of thrusts	No. of obs.	Time	No. of thrusts	No. of obs.
Cuba	9.0″	20.0	1	6.0″	15.0	1	9.0″	25.0	1
Josie	8.3″	17.1	11	6.7″	10.7	3	...	...	..
Mamo	15.3″	29.0	4	...	...	..	9.7″	21.4	9
Mimi	8.0″	13.3	6	6.9″	11.8	10	6.7″	16.6	14
Nana	9.0″	18.6	7	7.0″	12.0	1	6.5″	13.5	2
Wendy	9.1″	19.9	11	7.1″	12.4	14	...	...	..
Gen. avs.	9.8″	19.7	40	6.7″	12.4	29	8.0″	19.1	26

Individual variations among males with respect to the influence of the sexual status and traits of the female are extreme. One male, for example, may consistently refuse to mate with a given female, or he

may accept her only for a few days — almost certainly those approximating the time of ovulation (Elder, 1938) — during the normal sexual cycle. Another male, by contrast, may eagerly accept or even insistently solicit the same female throughout the three phases of genital swelling, and even when her sexual receptivity is very slight. Similarly, a female consort may consistently refuse one male and in the next minute eagerly mate with another. Our records supply many instances of such unexpected sexual refusals. In many of these cases of anomalous sexual behavior the essential condition seems to be social incompatibility, but this of course may trace to the influence of physique, of immediate behavior, or of preference for another mate over the one at hand. Occasionally in cases of the unexpected rejection of a consort, we have observed conflict of motives. The following instance is cited illustratively.

Wendy, on cycle day 15, when known to be fully receptive and willing to mate with Bokar, definitely rejected Pan, although he evidently expected and desired her to present sexually. On the following day she again refused to go to him. On day 17, Pan, by genital gesture, solicited presentation, and Wendy responded vocally but without at first approaching him. In the fourth minute of the experimental period, the male again solicited her by postural and genital gestures. In response she descended from the netting of the cage-wall and flattened out on the floor a few feet in front of him. Accepting her behavior as permission or invitation to mate, Pan started to approach, but before he reached her she sprang up, whirled about, and viciously attacked him. Surprised and manifestly disappointed, Pan instantly became defensive, but not aggressive. To safeguard the animals a stream of water was immediately brought into play and they were separated.

Our interpretation of this incident is that the female, while strongly negative socially toward Pan as mate, was dominated momentarily by her strong sexual receptivity and started to respond appropriately. As the male approached, her negativism to him became dominant and she suddenly assumed an attitude of defense. This behavior is peculiarly interesting because Pan and Wendy had lived together in these laboratories for several years during childhood and adolescence in harmonious intimacy.

Pan, the vasectomized male, was rejected by Josie as well as by Wendy. Nana refused to mate with him except during maximal

receptivity.[8] Ordinarily he proved acceptable to Mimi, Cuba, and Mamo. We grant the possibility that the females in this instance perceived the unusual or relatively unsuitable in his physique or sexual behavior and responded to him accordingly. The sterilization operation may have lessened his aggressiveness or his copulatory vigor. Prior to it he had

TABLE 9

Dominance-subordination, female timidity, and male aggressiveness ratings for each animal

AVERAGES FOR MALE SUBJECTS*

Males	D - S of F	D - S of M	T of F	A of M	Number of observations		
					+ scores	Zeros	Total
Bokar	—1.07	0.71	0.41	0.27	28	44	72
Jack	—1.13	0.76	0.85	0.59	30	61	91
Pan	—1.11	0.80	1.02	0.43	37	33	70
Gen. avs. and totals	—1.10	0.76	0.76	0.43	95	138	233

AVERAGES FOR FEMALE SUBJECTS

Females	D - S of F	D - S of M	T of F	A of M	Number of observations		
					+ scores	Zeros	Total
Cuba	—1.56	1.11	1.00	0.56	8	2	10
Josie	—0.93	0.79	0.90	0.52	9	25	34
Mamo	—1.23	0.59	1.10	0.40	21	26	47
Mimi	—0.83	0.75	0.55	0.38	15	43	58
Nana	—1.00	0.79	0.44	0.28	21	19	40
Wendy	—1.07	0.50	0.54	0.42	21	23	44
Gen. avs. and totals	—1.10	0.76	0.76	0.43	95	138	233

* Averages are for those experimental matings in which at least one positive score occurs. All other observations are included under zero scores.

[8] This was true before vasectomy (Yerkes and Elder, 1936, p. 28) as well as after it.

been one of our most vigorous breeding males. The facts of behavior and circumstance do not convince us that vasectomy affected the relations of this male with Wendy and Josie.

Measurements of male and female dominance-subordination, of female timidity, and of male aggressiveness, as exhibited in Table 9, reveal the dominance of M and the subordination (all negative values) and timidity of F. Without doubt the social relations measured importantly affect the mating pattern.

It appears from our records that other than zero ratings for dominance-subordination *et al.* are infrequent, save at the beginning of a series of experimental matings, when aspects of the situation are relatively unfamiliar to the consorts; when a new male instead of the one expected appears; or when a male is used whose affective relation to the female is unfavorable.

Upon our statistical findings we base these general statements of relationship. The dominance-subordination values for the several males do not differ significantly and reliably. The opposite, however, is true for the timidity and acceptability data, as the several males differ greatly in acceptability and evoke varying degrees of timidity in the females (Pan, 1.02; Jack, .85; Bokar, .41).

The individual female differences for all males are highly significant. In order of their subordination to the male the subjects rank: Cuba (—1.56), Mamo, Wendy, Nana, Josie, Mimi (—.83). Mamo and Cuba exhibited greatest timidity, Wendy and Nana least. Toward Cuba and Josie male aggressiveness was greatest, toward Nana and Mimi it was least.

For our series of 233 mating experiments the frequency and the total time of grooming are given for each male and for each pair of consorts (Table 10). The time is approximate, because the minimum unit of measurement was one minute. Analysis of our materials justifies the statement that the nature and frequency of grooming, as pattern of social behavior (Yerkes, 1933, p. 4), are indicative of the character and strength of the affective bond between consorts.

The order of sexual acceptability of the males (Table 7) is also the order of frequency with which the male is groomed by the female (Table 10), and, as a corollary, the less acceptable a male—unless he be completely rejected and dominated by the female—the more eager he is to groom his consort. For the male this variety of social activity appears to be a way of currying female favor or of cultivating

TABLE 10

Incidence of grooming during mating experiments

FEMALE	MALE											
	Bokar				Jack				Pan			
	F × M		M × F		F × M		M × F		F × M		M × F	
Cuba	0*	0**	0	0	0	0	0	0	2	2′	2	3′
Josie	2	4′	7	20′	0	0	3	9′	2	6′	2	7′
Mamo	0	0	0	0	0	0	1	2′	4	6′	0	0
Mimi	2	6′	2	2′	3	4′	1	2′	8	10′	1	1′
Nana	3	6′	2	4′	0	0	0	0	2	6′	1	4′
Wendy	3	6′	14	42′	0	0	13	39′	0	0	0	0
Totals for males	10	22′	25	68′	3	4′	18	52′	18	30′	6	15′

* Frequency of grooming.
** Total time.

friendly acquaintance, while for the female it seems instead to be a way of diverting the male from sexual behavior, when the female is of low receptivity, and of continuing contact with him following sexual union. Assuredly in the mating experiment, grooming, as a rule, is expressive of desire on the part of one or both consorts to encourage friendly, coöperative relations, or to maintain intimate bodily contact.

VI. SEXUAL RELATIONS DURING PREGNANCY

In their description of oestrus in the chimpanzee, Yerkes and Elder (1936, p. 38) state: "Our observations point the fact that copulation does not normally occur during menstruation, gestation, and lactation. During these sexual and reproductive states the female does not manifest oestrus or strong sexual desire, and she usually has no sexual appeal for the male." This generalization must be modified somewhat, since our receptivity ratings in the present series of experiments prove that, during genital swellings which occur in the course of pregnancy, a female may exhibit varying degrees of sexual responsiveness and may copulate.

As has been elsewhere reported (Elder and Yerkes, 1936, p. 131), typical menstrual cycles do not ordinarily occur during pregnancy, although non-bleeding, swelling cycles may appear. They are most likely in the first two or three months of gestation, and they tend thereafter, when appearing at all, to be short or irregular. An illustrative case is that of Wendy, who, following impregnation in the cycle which is represented by Fig. 3A, exhibited a swelling cycle in the first month of her pregnancy (Fig. 3B), which, apart from the absence of menstruation, macroscopically resembled her normal swelling cycle. Maximal swelling was attained speedily, lasted for eleven days, and then in a few hours disappeared. Mated with Jack (once with Bokar, 36th day) during this incomplete cycle, she proved non-receptive at the beginning of tumescence, later became highly receptive, and so continued for about a week, whereupon receptivity disappeared with the completion of detumescence.

The second pregnancy swelling (Fig. 3C) differs from the first in being smaller, of shorter duration, and slower in disappearing. The sexual behavior of Wendy during this period was as unlike that in the typical non-pregnant sexual cycle as was the swelling. Again Jack was used as consort. At the beginning of the swelling the female was wholly non-receptive, *but mating nevertheless occurred,* as at the beginning of cycle B. Then over an interval of three days receptivity increased to a maximum, which continued for two days, and was followed by a non-receptive copulatory mating, and subsequent unpredictableness of receptivity and of mating response.

The following generalized description is in order. The sexual behavior of the pregnant chimpanzee differs ordinarily from that of the non-pregnant individual in several important respects, which may here be listed merely, instead of adequately described. They include: (a) lower receptivity, (b) greater variability of behavior, (c) low predictability of behavioral features, receptivity, and mating, (d) less definiteness, consistency, and decisiveness of behavior, (e) less satisfactory coöperation with the male in mating, and (f) greater vacillation and irritability. Seemingly positive pregnancy matings do not necessarily imply sexual receptivity or desire in the female.

Suggested by our observations relative to matings during pregnancy are these queries: Are responsiveness and copulation determined chiefly by the attitude, expectation, and appeal or command of the dominant male? Is the pregnant female merely protective, defensive, or accom-

modating in the absence of oestrus and possibly also of sexual desire? Are our receptivity ratings for the pregnant individual incomparable with those ordinarily obtained? We are inclined, on the basis of available information, to answer each question affirmatively. We conclude tentatively that pregnancy receptivity is an artifact, due to the reflection by the female of the sexual dominance of her consort. She is necessarily protective under the conditions of experimental mating, whereas if free she probably would avoid or escape the attentions of the male. It seems that the presence of genital swelling is at least initially accepted by the male as a sign of female receptivity. Ordinarily a female may be able to correct misinterpretation of this sign, but the pregnant female dare not risk attack.

VII. SUMMARY

1. With a previously published account of oestrus in the chimpanzee as background, this paper presents further results of inquiry into the nature and conditions of sexual responsiveness and mating behavior. Methodologically it differs from our previous study in that a rating scale was systematically used to measure the responsiveness and mutual acceptability of consorts. Observations were made in a total of 233 experimental matings, for which six females and three males served as subjects. A vasectomized male was available to minimize the risk of undesired pregnancies. So far as feasible, observations were made throughout sexual cycles at intervals of one to two days.

2. Female receptivity exhibits periodicity, as does genital swelling, and concurrently with it. In general, its fluctuations during the five-week sexual cycle range from zero, during the menstrual and post-menstrual cycle phases, to a maximum strength at a point, presumably hormonally determined, between the middle and end of maximal swelling. With the onset of detumescence it falls to zero and continues in abeyance for the remainder of the cycle.

3. A period of "heat," or, in our terminology, maximal receptivity, is characteristic of the chimpanzee cycle. Its duration has not been satisfactorily determined, since the methods employed do not eliminate the influence of the male, and consequently measure a social response which is determined by the physiological status of the two consorts. It is indicated that receptivity waxes gradually, achieves a maximum, and presently disappears suddenly. The duration of "heat" probably can

be reliably determined only by direct measurement of the isolated female. Suitable methods are being sought.

4. Completion of the mating pattern by copulation does not necessarily imply female receptivity even in low degree, since the male consort may dominate and command the female and she may respond defensively, protectively, or accommodatingly *in the experimental mating situation,* whatever her sexual status, desire, or preference.

5. A fully receptive female may on occasion repulse the advances of a responsive male, or the reverse may occur. In either case the consort which was non-coöperative may mate promptly with another individual. Such selectiveness usually seems to be due to physical incompatibility, individual preference, or unfavorable affective relations. The ability of females to control a male in the mating situation differs extremely.

6. Highly indicative of the nature of receptivity are these items of behavior: (a) The initial movement of the consorts when the barrier between their cages is removed, for F usually rushes into M's cage if highly receptive, while he awaits her presentation; (b) the fact and manner of presentation by F to M, for if fully receptive she runs to him and prostrates herself before him; (c) the duration of sexual union and the behavior of F during the act; (d) efforts of F to remain with M after the completion of the mating experiment.

7. Female sexual preference and perfection of coöperation in mating appear to vary directly with such male traits as sexual vigor, robustness, penis length, and the nature of the copulatory act, and inversely with male dominance and aggressiveness. The correlations evidently are worthy of careful statistical determination and verification.

8. Typically, sexual receptivity is absent or low during menstruation, and copulation rarely occurs, and then by male domination. During pregnancy it ordinarily is absent except in periods of genital swelling. When a pregnant female exhibits marked swelling she tends to excite the male sexually and copulation may occur. In some instances it appears that receptivity is of considerable strength, while in others mating obviously is due to the expectancy and responsiveness of the male as induced by the visual sign, swelling. Under such circumstances, and lacking opportunity to escape, the female may not safely risk struggle with the male. Instead she responds protectively and accommodatingly, irrespective at times of sexual desire.

9. Our observations suggest the hypothesis that "heat," as periodicity of female receptivity, is characteristic of the primate as of many of the mammals; that it varies in frequency from type to type; that the inadequacy or unreliability of observations and interpretations probably is responsible for erroneous statements and prevalent misunderstandings concerning the pertinent facts of human life. At present our observational techniques are inadequate. Obviously methods should be developed which will render possible measurement of sexual receptivity and responsiveness objectively in the isolated individual. Meantime, the rating scale, as used in this inquiry, has taken us a step nearer our goal.

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STATISTICAL CONTRIBUTIONS FROM THE MENTAL HYGIENE STUDY OF THE EASTERN HEALTH DISTRICT OF BALTIMORE

III. PERSONALITY DISORDER IN THE EASTERN HEALTH DISTRICT IN 1933

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INTRODUCTION

THE Mental Hygiene Study, in its 1933 survey of mental hygiene problems in the Eastern Health District of Baltimore, discovered 1310 recorded cases which could be classified as personality deviates, i.e., as showing recognizable inadequacy in capacity for personal and social adjustment. In this paper, these cases are discussed in relation to their distribution by race, sex and geographical subdivision, and those of the white race in relation to their association with certain social and economic factors.

The group was selected from a total of 2496 mental hygiene problems found by the study to have been recorded by some agency or institution in 1933. (See the introductory report (1) in this series for a general description of the survey and the material.) Of the 1186 cases not classified as personality deviates, 229 were in institutions throughout the year. These were excluded because descriptions of their personalities and behavior, as of the year 1933, were difficult to obtain, and of doubtful significance because of the circumstances and possible effects of institution life.

The remaining 957 cases were excluded because, so far as their records show, they did not present sufficient evidence of serious personal or social maladjustment. No general rule could be laid down for making this differentiation; each case had to be evaluated in terms of the total

picture presented. In selecting out the personality deviates, judgments were made conservatively and the classification of personality disorder was reserved consistently for those cases in which this diagnosis was quite clearly indicated. In general, such indication was in the form of a definite statement of serious maladjustment, or a sufficient description of behavior and personality distortion to leave no doubt of such maladjustment. The personality deviates include, in addition to psychotics, psychoneurotics, and psychopathic personalities, some post-psychotics and epileptics, and a good proportion (47 per cent) of those classified as "maladjusted".

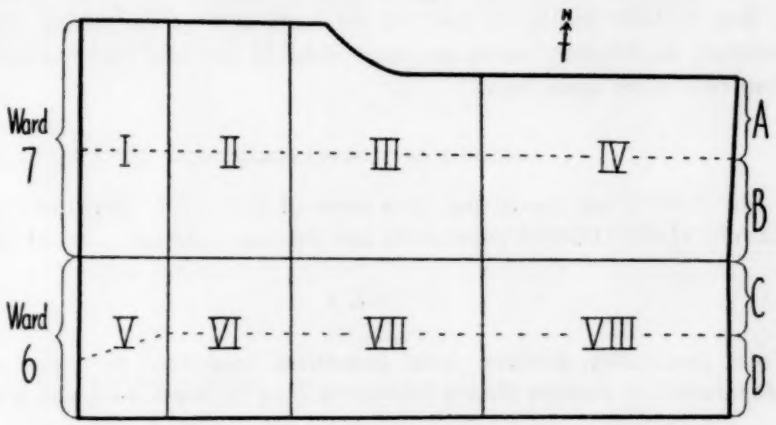

FIG. 1. OUTLINE OF EASTERN HEALTH DISTRICT WITH PRINCIPAL SUBDIVISIONS AND THEIR DESIGNATIONS

The Eastern Health District is shown schematically in Figure 1. It is nearly rectangular in shape, and extends about 0.8 mile from north to south and 1.3 miles from east to west. The total area is approximately one square mile. It is made up of two political wards of the city, Ward 6 on the south and Ward 7 on the north. Each ward is divided into four subdivisions, numbered I to IV in Ward 7 and V to VIII in Ward 6, from west to east. A further useful division of the whole area is made by separating each ward into two parts by means of the east-west street closest to the mid-point between northern and southern boundary, shown by the horizontal broken line. The four sections thus formed are labelled A, B, C, and D, from north to south.

The residents of the district represent for the most part the lower economic level of the city's population, although not necessarily the lowest. The general character of environment as indicated by types of homes and neighborhood is not uniform throughout the district, showing a steady improvement in going from west to east. On the west the district adjoins one of the worst slum areas of the city with no clear differentiation at the margin, and the population is largely Negro. The eastern end is a typical lower middle class white neighborhood, neat and orderly in appearance. On the whole, the two wards are quite similar in general environmental characteristics, so far as can be seen from gross inspection. The improvement in neighborhood from west to east is seen in both wards, so that for the most part two adjoining subdivisions in different wards are more alike in physical characteristics than two in the same ward.

ANALYSIS OF THE MATERIAL

In Table 1 are shown the 1310 cases of personality deviation, the Eastern Health District population, and the case rate per 1000 of the

TABLE 1

Total personality deviates, total population, and rate per 1000 of population, of Eastern Health District in 1933, by ward, race, and sex

		WARD 6			WARD 7			TOTAL
		White	Negro	Total	White	Negro	Total	
Cases	Male	363	95	458	179	138	317	775
	Female	300	40	340	117	78	195	535
	Total	663	135	798	296	216	512	1310
Population	Male	11237	2046	13283	10223	3915	14138	27421
	Female	11603	2134	13737	10615	4267	14882	28619
	Total	22840	4180	27020	20838	8182	29020	56040
Rate per 1000	Male	32.30	46.43	34.48	17.51	35.25	22.42	28.26
	Female	25.86	18.74	24.75	11.02	18.28	13.10	18.69
	Total	29.03	32.30	29.53	14.20	26.40	17.64	23.38

population, by ward, race and sex. The total crude rate for the district is 23.38±0.64. For the two wards, however, the rates are very different, the excess of Ward 6 over Ward 7 being 11.89±1.28. The difference persists in each of the race and sex groups except Negro females; in the others the differences are all significant (Table 2a).

In both wards and both races the male rates are appreciably higher than the female, with all differences significant (Table 2b). In general, the Negro rates exceed the white rates, the only exception being among the females of Ward 6 where this relationship is reversed. The difference in this case, however, is of doubtful significance, whereas the excess of Negro rate over white in the other groups is well beyond sampling error (Table 2c).

TABLE 2a

Ward 6 rate minus Ward 7 rate:

White males	14.79 ± 2.14
White females	14.84 ± 1.52
Negro males	11.18 ± 5.29
Negro females	0.46 ± 3.57

TABLE 2b

Male rate minus female rate:

Ward 6 whites	6.44 ± 2.22
Ward 6 Negroes	27.69 ± 5.47
Ward 7 whites	6.49 ± 1.61
Ward 7 Negroes	16.97 ± 3.55

TABLE 2c

Negro rate minus white rate:

Ward 6 males	14.13 ± 4.38
Ward 6 females	—7.12 ± 3.66
Ward 7 males	17.74 ± 2.78
Ward 7 females	7.26 ± 2.06

All the differences shown in Table 1 are probably worth further investigation. The present study will be confined, however, to detailed analysis of the difference in rate of personality problems between the two wards among whites.

The greater part of the information available for such study is provided by the 1933 census[1] of the district so that the analysis will need to be confined to those cases for which this information is known. About 74 per cent of the white cases are specifically enumerated in the census, and an additional 8 per cent could be identified with a census household. The remaining 18 per cent are entirely without representation in the census and their records consequently lack much of the data which the census schedules furnish.

TABLE 3

White personality deviates identified with census individuals or households, rate per 1000 of total white population, and ratio of this rate to corresponding rate of Table 1, by ward and sex

	Ward 6			Ward 7		
	Male	Female	Total	Male	Female	Total
Cases	300	240	540	150	95	245
Rate per 1000	26.70	20.68	23.64	14.67	8.95	11.76
Ratio to corresponding rate of Table 1	.83	.80	.81	.84	.81	.83

In Table 3 are shown the white cases enumerated in the census or identified with a census household, and their rates per 1000 of the population. In the last row of the table are given the ratios of these rates to the corresponding rates of Table 1. From these it can be seen that the relative change in their magnitude produced by omitting the cases not identified with individuals or households of the census is very uniform through the four groups, so that there results no change in the relations between them.

For both sexes combined, the rate for Ward 6 is 23.64 ± 0.88 and for Ward 7, 11.76 ± 0.92 per 1000 of the population. The difference is 11.88 ± 1.27. (No error is introduced by combining the two sexes, since their ratios to each other are practically identical in the populations of the two wards: the ratio of females to males is 1.032 in Ward 6 and 1.038 in Ward 7.) The distribution of cases and rates by age groups, and the age corrected rates, by ward, are shown in Table 4.

[1] A brief description of the census is given in Reference 1.

The difference between the corrected rates is of the same magnitude as that between the uncorrected rates, so that the latter is not due to differences in age composition between the two populations.

TABLE 4

White personality deviates and rate per 1000 of population by 5-year age groups below age 20, and 10-year age groups thereafter, with age corrected rate, by ward, and difference between wards

AGE GROUP	CASES		RATE PER 1000	
	Ward 6	Ward 7	Ward 6	Ward 7
0-4	9	3	5.62	2.09
5-9	46	18	21.84	10.11
10-14	112	65	45.62	31.31
15-19	58	30	25.88	14.75
20-29	77	36	19.24	9.90
30-39	90	37	26.74	12.30
40-49	91	31	31.90	10.91
50-59	40	16	20.64	8.90
60-69	13	7	10.70	6.48
70-79	4	2	7.01	3.45
Age corrected rate*			24.12	12.17
Difference			11.95	

* Population of two wards combined used as standard.

One conspicuous difference between the two wards, indicated in the population figures of Table 1, is in their relative proportion of Negroes. Ward 6 is 15.5 per cent Negro and Ward 7, 28.2 per cent. The Negroes are confined largely to the western third of the district, and occupy roughly the same relative position in both wards. They are found almost entirely in subdivisions I, II, V, and VI, making up in fact the greater part of the population of subdivisions I and V. The white rates by subdivision are compared with the percentage of Negroes by subdivision in Table 5. The relations shown by these figures seem clear. In either ward, passing from subdivision with highest proportion of Negroes eastward to that of lowest proportion, the proportion of whites with problems decreases. In Ward 6 the trend is quite pronounced.

TABLE 5

White personality deviates, rate per 1000 of population, and percentage of Negroes in the population, by subdivision

Subdivision	WARD 6 V	VI	VII	VIII
No. of cases	33	160	230	117
Rate per 1000	50.77	42.27	28.63	11.34
Per cent Negro	78.7	27.3	3.8	0.3
Subdivision	**WARD 7 I**	**II**	**III**	**IV**
No. of cases	20	39	106	80
Rate per 1000	18.23	18.84	12.80	8.52
Per cent Negro	80.1	63.2	2.2	0.1

These data contribute further evidence to support the difference in rate between whites of the two wards, since they show a marked persistence of the difference when the rates are specified by subdivision. The association of white problems with Negro neighborhoods, moreover, holds only within wards. When the rates for the eight subdivisions are distributed only in respect to changing proportion of Negroes and without regard to geographical position, a consistent trend is no longer seen. The difference between the wards seems, therefore, of considerably greater significance than the relationship of cases to Negro neighborhoods.

The white populations of the two wards differ very greatly in their proportions of Jews. The fact of this difference between the wards was known in a general way, even though religious affiliation was not included in the census, since the lower portion of Ward 6 includes part of a large Jewish neighborhood which extends southward and southwestward from the district. In the light of the difference in rate of personality problems between the whites of the two wards it became essential to know the distribution of Jews in the district as accurately as possible.

The only available method for obtaining this information was to separate the white families into Jews and non-Jews by means of their

names. The original family schedules of the census were gone through and those of the white families examined for character of name, and likewise for any other indication that might suggest or support the possibility of their being Jewish. Despite the seeming uncertainty of the reliability of this procedure, the actual carrying out of the appraisal, which was done with considerable care, left little doubt that a very close approximation to the number of Jews was reached. The families whose grouping remained completely doubtful were very few, and in most cases the schedules of those which were somewhat doubtful furnished some evidence to allow a decision. Given names were frequently more useful than surnames, and occupation, type of school attended, names of non-resident relatives, and a variety of other kinds of facts were often helpful. Errors are probably for the most part random, except for the possibility that Jews are more likely to have non-Jewish names than non-Jews are to have Jewish names. For this reason the general error is believed to be in the direction of a slight under-estimation of number of Jews[2].

TABLE 6

Personality deviates, and rate per 1000 of population, among non-Jewish whites and Jews, by ward, with difference between wards

WARD	NON-JEWS		JEWS	
	Cases	Rate per 1000	Cases	Rate per 1000
6	344	19.25±0.91	196	39.79±2.70
7	223	11.21±0.86	22	23.40±6.19
Difference		8.04±1.25		16.39±6.76

[2] An indication of the size of this error is afforded by the fact that of 210 households in the study's files whose religious affiliation is reported as Jewish, 22 were not included in the appraisal. On the other hand four households reported as non-Jewish were included. In terms of individuals, 1055 are reported as Jewish, 100 were omitted in the appraisal, and 20 non-Jews were included. The net loss of 80 individuals represents an error of 7.6 per cent underestimation of the Jewish population. In the calculation of rates, however, the religion of cases is taken as appraised rather than as reported, so that the rates to be presented are adjusted in a measure for the error.

The authors are indebted to Dr. Christopher Tietze for his assistance in the appraisal of Jewish households.

In Ward 6, 4926 or 21.6 per cent of the whites, and in Ward 7, 940 or 4.5 per cent, were estimated to be Jews. Table 6 presents the cases and the rates per 1000 of the population, of non-Jews and Jews for the two wards. The rates for Jews are seen to be twice the size of those for non-Jews. The difference between the two wards, however, persists in both groups.

In view of the fact that the Jews are not evenly distributed in Ward 6 but are somewhat concentrated toward the southern boundary, it is useful to examine the rates for each of the divisions A, B, C, and D of Figure 1. The percentage of Jews in the total population (white and Negro) of these four divisions, in their order from south to north, are: D, 25.8; C, 10.4; B, 3.1; A, 3.4. Table 7 shows the cases and rates per 1000, of non-Jews and Jews in the four divisions, in this order. For both groups the rates for the two divisions of each ward are very similar, suggesting a sharp difference between the wards.

TABLE 7

Personality deviates, and rate per 1000 of population, among non-Jewish whites and Jews, by section, from south to north

WARD	SECTION	NON-JEWS		JEWS	
		Cases	Rate per 1000	Cases	Rate per 1000
6	D	177	19.59	143	40.43
	C	167	18.92	53	38.16
7	B	132	11.66	9	20.36
	A	91	10.60	13	26.10

In view of the great difference between the rates for Jews and non-Jews it is necessary to examine the association of white personality problems with Negro neighborhoods, discussed above, for these two groups separately. For this the division by ward may be ignored, the areas to be compared being formed by throwing together the pairs of subdivisions I and V, II and VI, III and VII, and IV and VIII. The rates for Jews and non-Jews in these areas, and the percentage of the population which is Negro, are given in Table 8. The observed association of personality problems with Negro neighborhoods is seen in both

TABLE 8

Rate of personality deviates per 1000 of population for non-Jewish whites and Jews, and percentage of Negroes in the population, by pairs of subdivisions from west to east

SUBDIVISION		I + V	II + VI	III + VII	IV + VIII
Rate per 1000	Non-Jews	21.31	25.97	18.53	10.00
	Jews	44.91	49.85	30.34	9.80
Per cent	Negro	79.6	45.9	3.0	0.2

groups. When broken down by ward, as in Table 5, the same relations are shown for the two groups as for the total whites (Table 9).

The relationships analyzed so far have been concerned, of course, with extremely broad environmental and biological factors. In pursuing the analysis farther it is clear that the difference in rate of personality problems between Jews and non-Jews requires that these two groups be treated separately in the study of any characteristics whose association with their problems are to be examined. Unfortunately it is not possible at this writing to retain this separation in respect to the other factors

TABLE 9

Rate of non-Jewish white and Jewish personality deviates per 1000 of the population, by subdivision

	WARD 6			
SUBDIVISION	V	VI	VII	VIII
Non-Jewish rate per 1000.....	39.28	34.93	26.71	11.31
Jewish rate per 1000.....	59.46	51.33	32.84	11.98
	WARD 7			
SUBDIVISION	I	II	III	IV
Non-Jewish rate per 1000.....	15.02	15.56	12.90	8.58
Jewish rate per 1000.....	26.84	40.59	10.10	....

that are available for such study. The appraisal of Jews in the district is at present in the form of a simple hand tabulation unrelated to the census data which is on punched cards, so that the distributions of other factors among Jews and non-Jews separately cannot be learned with a reasonable amount of labor until such time as opportunity and resources permit the repunching of the cards to include this differentiation.

It will be necessary, therefore, in the treatment that follows, to bear in mind the possible effects of this ethnic differentiation on the relations that are to be presented. The characteristics to be studied concern type of household: its size (i.e., number of individuals who comprise it), its economic status, and its housekeeping status.

TABLE 10

White personality deviates and rate per 1000 of population, by size of household, by ward

NUMBER OF INDIVIDUALS IN HOUSEHOLD		1, 2	3, 4	5, 6	7, 8	9, 10	11 & OVER
Ward 6	Cases	49	151	180	105	43	12
	Rate per 1000	19.56	19.28	24.19	31.76	32.26	28.10
Ward 7	Cases	14	81	83	40	19	8
	Rate per 1000	6.15	10.38	12.86	14.31	17.06	20.15

In Table 10 are shown, for whites of each ward, the number of cases and the rate per 1000 of the population among the individuals from households of varying size. In each ward the rate increases with increasing size of household. When the observed cases are compared with the number expected in random distribution, determined by redistributing the total cases according to the proportional distribution of the population, the departure of the observed distribution from the expected is significant in both wards. Likewise, in both wards there is a relative deficiency of cases in households with less than five members, and a relative excess in those with five or more members.

It is likely, however, that this trend is to some extent a consequence of the change in age distribution that probably occurs with increasing size of household. The great majority of the white households in the

district are known to consist of "biological families" only, that is, are households with all members in the same line of descent. In these, increasing size must result in a shift in average age to younger levels. The age specific rates of Table 4 show a very sharp peak in the age group 10-14, so that the trend in Table 10 must be due in part, at least, to a concomitant change in age distribution.

It would be desirable to examine this at first hand by studying the rates specified for both household size and age, but the population has not as yet been tabulated in this breakdown so that such a study must await further analysis of the census material. The possibility that a residual association of high problem rates with large households exists despite the age factor (and likewise, of course, the ethnic factor) will be left open. For the present there may be pointed out the persistence of the difference in rate between the wards in each size of household.

The information available concerning the economic situation of Eastern Health District households is not scaled on the basis of a quantitative rating, such as total family income. However, the census enumeration was carried out by experienced public health nurses in personal house-to-house visits, in the course of which they were required to make, by inspection of each house, an appraisal of its economic and housekeeping status, and to record this according to a defined scale. For economic status, the scale is as follows:

A. A household in which there is no question as to the adequacy of the bare necessities of life such as food and clothing and the comfortable heating of the home in cold weather. In addition, there may be evidence of a little surplus as indicated by such things as comfortable furniture, often a radio, and frequently a telephone.

B. A household in which indications of any surplus are absent and there is evidence that occasionally even the necessities are lacking.

C. A household in which food, clothing, and bare necessities are insufficient, and overcrowding usually evident.

While classification on this scale involves personal judgement to some extent, it can be seen that the evaluation was not entirely subjective since it took account largely of simple and tangible facts, of a kind readily appraisable by those familiar with public health investigation. There is, in fact, *a priori* reason for believing that such appraisal, if competently made, may represent a more valid picture of essential economic status than total family income, since it evaluates in terms of the use of income for family well-being, and avoids the assumption that income usually measures the degree of personal comfort. Such con-

siderations are important to mental hygiene. There is evidence that the appraisals were, on the whole, made conscientiously and accurately. Valaoras (2), in a study made with the data of the 1933 census of the Eastern Health District, found a definite association of higher rating of both economic and housekeeping status with the more permanent families, although the factor of length of residence was unknown to the nurses. He concludes (p. 7) that "they were exercising real judgment in making their grading".

TABLE 11

White personality deviates, and rate per 1000 of population, by economic status of household, by ward

ECONOMIC STATUS OF HOUSEHOLD		A	B	C	UNKNOWN
Ward 6	Cases	135	280	123	2
	Rate per 1000	11.48	31.82	66.34	..
Ward 7	Cases	85	120	38	2
	Rate per 1000	7.27	15.20	37.18	..

In Table 11 are shown the number of cases, the population, and the rate per thousand of the population, in white individuals of the two wards, by grade of economic status. The association of personality problems with lower grade of economic status is unmistakable in both wards, the rate rising steeply going from higher to lower grade. Again, however, the difference between the two wards persists in each grade, so that the demonstrated association of problems with poverty tells nothing about the more fundamental fact represented by this difference.

The general living conditions of families is of interest to mental hygiene equally with, perhaps even more than, their economic situation. There may be some doubt that the latter, which may be quite external to the psychobiological composition of a family, bears any essential deterministic relation to personality, particularly during a period of widespread economic difficulty such as existed in 1933. On the other hand it appears reasonable to postulate such a relationship in the case of mode of living, which seems intimately bound up with personality.

Most of the remarks about the reliability of the classification of economic status apply to the classification of housekeeping status. The definition of the scale by which the nurses evaluated housekeeping status is as follows:

A. A house that is clean, orderly and neatly kept
B. A house that is carelessly kept
C. A house that is dirty and neglected

While the estimation of economic status was in a sense a substitute for more precise quantitative data (but probably a valid and significant one as pointed out), this is not so of the classification of housekeeping status. It would be difficult, if not impossible, actually to measure such a characteristic, and its evaluation can be approached only by some such method as the one used. A complete description of such a factor throughout the whole of a population group is not often encountered, so that the study is fortunate to have this information available.

TABLE 12

White personality deviates, and rate per 1000 of population, by housekeeping status of household, by ward

HOUSEKEEPING STATUS OF HOUSEHOLD		A	B	C	UNKNOWN
Ward 6	Cases	241	224	64	11
	Rate per 1000	15.33	41.13	76.83	..
Ward 7	Cases	154	80	8	3
	Rate per 1000	9.62	20.88	36.04	..

Table 12 shows the number of cases, the population, and the rate per 1000 of the population, in white individuals of the two wards, by grade of housekeeping status. The association of problems with poorer housekeeping status is seen to be very marked in both wards, and again the Ward 6 rates are consistently higher than those of Ward 7.

The effect of combining the two characteristics of economic and housekeeping status is shown in Table 13. Except for the absence of cases in households with economic status A and housekeeping status C,

TABLE 13

Rate of white personality deviates per 1000 of population, by housekeeping status, by economic status, by ward

	HOUSEKEEPING STATUS		A	B	C
Economic Status	Ward 6	A	10.43	25.84	....
		B	23.78	39.87	55.15
		C	43.01	64.21	91.76
	Ward 7	A	7.11	13.03	....
		B	12.99	19.35	30.00
		C	33.04	42.45	49.02

the rates in each grade of either characteristic increase with decreasing grade of the other characteristic. Likewise at every level the Ward 6 rate is higher than that of Ward 7.

DISCUSSION

Since the investigation in its present stage is incomplete, no attempt will be made to interpret the observed relationships as fully as possible until the further studies indicated have been carried out. Work on this is now under way.

However, what has been observed so far appears to be of interest. Those aspects of the expression of personality disorders that are measured by prevalence rates seem to be distributed in the district in some sort of pattern, showing several gradients that suggest combinations of associations with different factors. High white rates are found to be associated with both the "Negro neighborhood" and the "Jewish neighborhood". These designations, however, are used merely descriptively and without the intention of indicating causative factors. Exactly what it is in those neighborhoods with the higher rates that is responsible for them cannot be demonstrated at present. Speculative possibilities are nearly unlimited, but hardly seem worthwhile at this stage.

The group of cases analyzed includes, of course, varying degrees of severity of illness or maladjustment. This variability, which is not taken into consideration in the present study, suggests itself as playing some part in determining certain of the observed differences. That this

is not likely can be seen from the fact that among the several reaction types[3] under which the cases are ultimately classified, and which take into account such differences in severity, every reaction type shows an appreciably greater number of cases in Ward 6 than in Ward 7. Furthermore, in the excluded group of institutionalized cases, which are, of course, the most severe ones, there are likewise more from Ward 6 than from Ward 7.

As pointed out in the course of presenting the data, the study of the association of personality problems with household characteristics, as here developed, is merely the first approach toward a more extensive and more detailed analysis of these and similar relationships. Some of the factors that need further examination are clearly indicated; others will no doubt appear as the investigation continues. In addition such characteristics as nativity, family composition, crowding within the home, more general population density, certain specific features of neighborhood environment, and the like, will be examined.

An important question concerns the usefulness of the rates that have been presented, particularly those of Table 1, as measures of comparative prevalence. The cases whose relative frequencies they represent are rather specially defined, as a group, and as definitely circumscribed as possible. This results in limitations as well as advantages. The definition of personality deviation as here employed is dependent on the nature of the study and its material, which is to say, on the particular area under investigation with its particular resources for case finding and recording. The determination of comparable rates for other areas requires not only fairly close duplication of the methods by which these cases were obtained, but also that the sources of information be comparable in kind and in degree of efficiency.

Probably the rates presented will find their greatest usefulness, at least for some time, in the continued study of the Eastern Health District, in the determination of trends over long time periods and in the types of internal comparisons with which this analysis deals. However, since the field under investigation is still largely unexplored it seems that for the time being this limitation must be accepted.

SUMMARY

1. Of 2496 mental hygiene problems discovered in the Eastern Health District of Baltimore in 1933, 1310 are classified as personality

[3] These are stated in the introduction; a fuller account is given in Reference 1.

deviates on the basis of clear-cut evidence of inadequate personal and social adjustment. The case rate of personality deviates is 23.38±0.64 per 1000 of the total population.

2. The two major geographical divisions of the district, Wards 6 and 7, differ appreciably in their rates, that of Ward 6 being 29.53±0.92, and of Ward 7, 17.64±0.89. The difference is 11.89±1.28. Of the four principal race and sex groups, white and Negro males and females, this difference is reflected in all except Negro females.

3. Male rates are consistently and significantly higher than female rates.

4. Negro rates exceed white rates except among the females of Ward 6.

5. Further detailed analysis in this paper is confined to the difference between the two wards among whites. Omitting cases not identifiable with census individuals or households, the white rate for both sexes combined is 23.64±0.88 in Ward 6 and 11.76±0.92 in Ward 7, the difference being 11.88±1.27.

6. The difference between the white rates of the two wards is not due to differences in age composition of their populations.

7. Within each ward the white rates for smaller subdivisions are highest in those subdivisions with largest proportion of Negroes and decrease with decreasing proportion of Negroes. The trend is quite pronounced in Ward 6.

8. Most of this trend is not observed if the separation by ward is disregarded. Furthermore, comparing neighboring pairs of subdivisions in different wards, the Ward 6 rates are consistently higher than those of Ward 7. Accordingly, the difference in white rate between wards is of greater significance than the association of white cases with Negro neighborhoods.

9. The proportion of Jews in the two wards is very different: The white population of Ward 6 is estimated to be 21.6 per cent Jewish and of Ward 7, 4.5 per cent. Likewise, the case rates of Jews and white non-Jews differ greatly, being 37.16 ± 1.74 per 1000 for the former and 15.01 ± 0.68 for the latter.

10. The difference in white rate between the two wards is found in both non-Jews and Jews.

11. The association of higher rates with Negro neighborhoods within wards is seen in both non-Jews and Jews.

The possibility that social and economic factors play important rôles in the foregoing relationships is indicated by the following facts, in which the differentiation of the population into Jews and non-Jews is not taken into account:

12. The rate of personality deviation increases with increasing size of household (i.e., number of individuals in the household). This trend is probably due largely to a change in age distribution with increasing size of household.

13. The rate increases as the economic status of the household decreases.

14. The rate increases as the housekeeping status (i.e., degree of care in household management) becomes worse.

15. In the trends in rate with all three of these factors, size, economic status, and housekeeping status of the household, the difference between the two wards persists in every grade of each factor.

16. Interpretations and conclusions are withheld for the present, since further and more detailed analysis of these and other relationships is now under way.

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LUNG CANCER AMONG MINE WORKERS IN JOACHIMSTHAL[1]

BY SIGISMUND PELLER, M.D.

I. INTRODUCTION

SINCE 1878 it has been known that lung cancer is very frequent in the Schneeberg mines in Germany. During the period 1875-1912, there died 662 miners, 332 of whom succumbed to cancer; 87 percent of the primary tumors originated in the lungs (Arnstein, Uhlig). To be sure, autopsies were seldom made. However, after the World War, when autopsies became more frequent, a still higher percentage of cancer deaths and a still higher proportion of lung cancers were shown to occur (Schmorl and co-workers). These puzzling peculiarities have been connected with various factors acting upon the lungs.[2] Recently, it was shown that out of 48 mice kept for about a year in the Schneeberg mines, 28 died, 7 of them having developed an intrathoracic tumor (Döhnert).

The cancer mortality rates are not less puzzling than the proportion of lung cancers. During 1875-1894 there were employed, on the average, 636 miners, of whom 9.6 died yearly of cancer. In the years 1895-1912 there were annually, on the average, 417 miners with 7.8 deaths. To what extent the cancer mortality rates of the miners differ from the usual figures may be seen from Table 1. The comparison figures from Vienna are for recent years in which lung cancer is more frequently registered than in pre-war times.

Across the border in Czechoslovakia not far from Schneeberg, there are the famous radium mines of Joachimsthal.[3] In 1929 the existence of lung cancer among the miners and radium workers in Joachimsthal

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[1] From the Department of Biology of the School of Hygiene and Public Health, Johns Hopkins University, Baltimore, Maryland, U.S.A.

[2] Arsenic, pneumoconiosis, silicosis, radioactivity.

[3] The small mining town Joachimsthal is of historic interest, having furnished the first widely used American currency, called "Joachimsthaler", later shortened to "Thaler" and finally changed into "Dollar".

TABLE 1

Crude cancer mortality per 1,000

	MINERS IN SCHNEEBERG		VIENNA, MALES 15-79 YEARS OF AGE
	1875-1894	1895-1912	1932-1936
Lung cancer.....	12.7 ± 1.0	16.5 ± 1.5	0.34
Cancer of other organs	2.4 ± 0.4	2.1 ± 0.6	2.10
Cancer of all organs..	15.1 ± 1.1	18.6 ± 1.6	2.44

was revealed (J. Löwy). Since then the Czechoslovakian Ministry of Health has been interested in this problem. The Ministry collected what data were available as far back as 1846, and also ordered postmortem examinations. Autopsies were performed on 13 of the 20 miners and pensioners who died in the years 1929-30 and on *all* deceased miners and pensioners of the years 1933-1938. Almost all the postmortem examinations were carried out by Dr. Sikl, head of the Pathological Department, Karel University, Praha.

Ministerialrat Dr. Gruschka of the Ministry of Health kindly put the data at my disposition. For the translation of the reports, I am indebted to Sektionsrat Dr. Wohak. These data gave me opportunity for continuing my studies on the rôle of irritation in cancer incidence and in the distribution of tumors according to the organ affected.

2. CANCER MORTALITY IN JOACHIMSTHAL

Before the World War, 24.6 percent of all deaths and 46.6 percent of the deaths among the miners were attributed to tuberculosis (Mahler). Six and four-tenths percent of all adult deaths and 15.5 percent of the deaths among the miners were considered due to cancer. Lung cancer among the miners was unknown then. During 1922-1928, the proportion of cancer deaths in the total population of Joachimsthal increased to 16.7 percent, whereas among the miners it remained on the old level. The average age at death, during 1846-1921, was for miners (51.2 years) about the same as for adult non-miners (51.5 years). In the years

1922-1928, the age at death of miners became lower (45.3 years) and that of all other adults rose (56.3 years).

The male population of Joachimsthal has high cancer mortality rates in the age groups 15-54 years. In the age group of 35-44 years the mortality is increased about 5 times, in the age group of 45-54 and 25-34 years about two to three times. In all other age groups of the male population and in all age groups of the female population, the cancer mortality rates are within the limits of the "normal" average.

TABLE 2

Cancer mortality per 1000

AGE (*years*)	BEZIRK JOACHIMSTHAL 1931-1937						PRAHA 1929-1932		VIENNA 1932-1936	
	Person-years		Cancer deaths		Rate per 1000		Cancer death rate per 1000		Cancer death rate per 1000	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
0-14	15268	14971	3	..	0.196	.....	0.038	0.013	0.036	0.022
15-24	9076	9887	1	..	0.104	.....			0.059	0.052
25-34	11506	10545	3	2	0.261	0.190	0.079	0.231	0.116	0.191
35-44	9222	10460	23	8	2.494*	0.765	0.488	0.876	0.516	0.834
45-54	5993	7876	26	16	4.33	2.030	1.860	2.218	2.037	2.280
55-64	4707	6078	28	29	5.95	4.77	6.05	4.43	5.96	4.435
65-74	3149	4035	37	47	11.75	11.65	11.79	9.08	13.28	8.60
75+	1106	1472	18	24	16.27	16.30	16.90	14.00	18.59	14.01

* ± 0.520.

Applying the age distribution of Praha to the male population of Joachimsthal, I find the cancer mortality of the 25-54 years old men to be 62.2 ± 2.8 per hundred thousand for Praha and 190.9 ± 26.7 per hundred thousand for Joachimsthal.

The age distribution is known for the dead miners and pensioners, but unknown for the living ones. The number of living miners and pensioners is only about 8 percent of the male population in the age

TABLE 3

Number of cancer deaths among males in Bezirk Joachimsthal, 1931-1937

AGE (*years*)	MINERS AND PENSIONERS	NON-MINERS
15-24	..	1
25-34	1	2
35-44	10	13
45-54	13	13
55-64	4	24
65-74	..	37
75+	1	17
Total	29	107

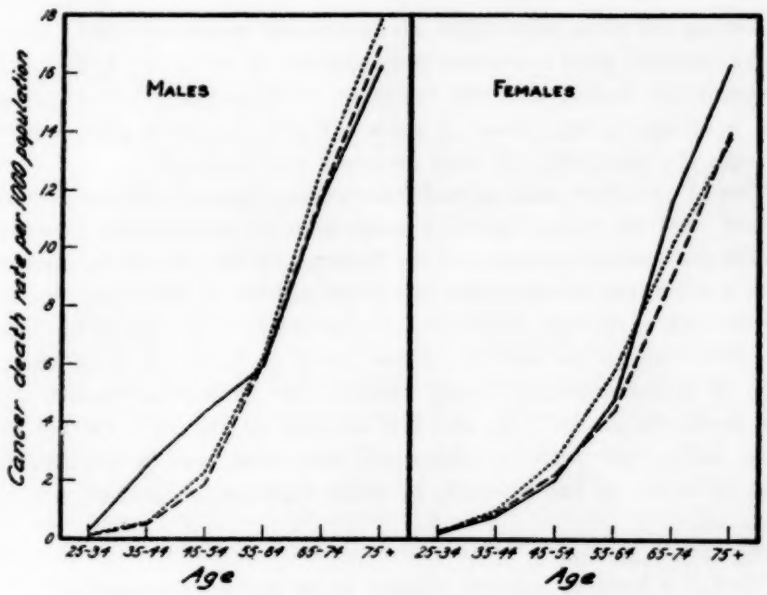

FIG. 1. CANCER DEATH RATES FOR MALES AND FEMALES SEPARATELY IN JOACHIMSTHAL (SOLID LINE); PRAHA (DASH LINE); AND NEW YORK CITY (DOTTED LINE)

period 15-54 years, but this miner and pensioner group accounts for 45 percent of the total mortality.

In the period 35-54 years, there are almost as many cancer cases of miners as among the total non-miner population. The number of deaths among the 35-54 years old non-miners is still high enough to make their cancer mortality greater than that of the same age groups in Praha or Vienna. In the ages above 55, the cancer rates for the non-miners are low.

The cancer incidence of radium miners in Joachimsthal is increased to such a degree that it raises the cancer incidence of the total male population of Joachimsthal in the age period 25-54 years to far above the level of Praha, London, Vienna or New York as is shown in Figure 1. It seems, however, that there are in Joachimsthal also other male groups showing a high cancer incidence, for example, the workers in the radium laboratory (about 60 laborers).

3. CANCER IN JOACHIMSTHAL RADIUM MINES

During the years 1929-1938[4], 89 miners and pensioners died. Sixty of the deceased were examined post-mortem; 47 cases, i.e. 52.8 ± 5.3 percent of all deaths, were due to cancer. The proportion of cancer is high in all age groups above 35 years. The cancer cases were, on the average, 47.3 years old; the other deceased, 46.6 years old.

Out of 47 cancer cases 43 had their primary tumor in the respiratory organs. Of the latter, 42 were considered as intrathoracic primary tumors and one as carcinoma of the larynx. Of the remaining 4 cases, there was one carcinoma of the face[5], two cancers of the stomach[6], and one sarcoma of the leg. Excluding the two years (1931-1932) in which autopsies were not performed, one has a total of 31 cancer cases, among them 28 intrathoracical primary tumors, one larynx carcinoma[7], and one carcinoma of the face, and one sarcoma of the leg. During the seven and a half years in which autopsies have been performed, no primary tumor of the stomach, of other digestive organs, of urinary

[4] Up to July 31, 1938.

[5] Died of a secondary infection, followed by mediastinitis phlegmonosa.

[6] Both these cases occurred in 1932, when autopsies were not performed.

[7] The only single case in which no autopsy was made in the year 1930.

TABLE 4

Miners and pensioners in Joachimsthal. Deaths according to the age and diagnosis

AGE (*years*)	EXAMINED POST-MORTEM 1929-1930, 1933-1938		NOT EXAMINED POST-MORTEM 1929-1932	
	Cancer	Non-cancer	Cancer	Non-cancer
-29	..	1	..	..
30-34	..	3	1	3
35-39	2	10	4	1
40-44	9	10	3	3
45-49	8	4	3	..
50-54	8	..	2	..
55-59	1	..	3	2
60-64	2	..	..	..
65-69	..	1	..	..
70-74	..	..	..	1
75-79	..	..	1	2
?	..	1	..	..
	30	30	17	12

organs, or of bones, etc., has been found. Therefore I am sceptical about the diagnosis of the two cases of "cancer of the stomach"[8].

In the 28 intrathoracical cancer cases, the autopsies twice revealed a second primary tumor in the lungs; in no case was a second primary tumor found in other organs.

Considering the non-cancerous deaths, the percentage of men who suffered primarily from a disease of respiratory organs is also very high. Thirty non-cancerous cases were examined post-mortem and 24 of these had died of lung diseases. Eighteen out of the 24 had died of tuberculosis pulmonum (4 cases combined with silicosis), three others had silico-fibrosis gravis without tuberculosis, one died of emphysema, one of pleuro-pneumonia and one of chronic bronchitis. One of the remain-

[8] It is quite possible that in the two cases the abdominal metastases diverted the attention from a quiescent primary tumor in the lungs, as before 1929, when lung cancer was unknown in the mines of Joachimsthal.

ing six died of chronic nephritis, one of syringomyelia; two miners succumbed to fatal accidents and two committed suicide.

Out of 28 cases of lung cancer, two died without metastases, 24 showed wide-spread metastases and in one case, only regional lymph glands were affected. In one of the 28 cases only a partial autopsy was performed. In one of the two cases without metastases the tumor, originating in the left bronchus, perforated into the oesophagus.

Table 5 shows the distribution of the metastases.

TABLE 5

Metastases in 24 cases of lung cancer in Joachimsthal

	CASES		CASES
Liver	14	Myo, epi- and pericardium	3
Bones	9	Brain	2
Kidney	7	Pancreas	2
Adrenals	6	Intestines	1
Lungs	5	Spleen	1
Pleura	4	Subcutis	1
Thyreoidea	4		

Table 5 shows more frequent metastases to the liver, bones, kidney, and adrenals than do other statistics of lung cancer (Jaffé, Samson, Stahr). The bone metastases were seen in the spine, ribs, skull, pelvis, and humerus. Metastases were found six times in one organ, nine times in two, five times in three, two times in four, and three times in five organs.

In the year 1929, there were reported to have been about 400 miners and 100 pensioners, a total of 500 persons. In 1937 there were 320 active miners and 80 pensioners, together about 400 persons. For all 9 years and 7 months[9], the cancer mortality was 10.9 ± 1.6 per thousand. For the 7 years and 7 months[10] in which autopsies were performed, the cancer mortality of the miners and pensioners was 9.2 ± 1.6 per thousand.

[9] 4300 person-years, 47 deaths.
[10] 3380 person-years, 31 deaths.

Table 6 breaks down the cancer mortality by site. In this table the (a) column includes all the years of observation, while the (b) column is for those years only in which autopsies were performed.

TABLE 6

Cancer mortality per 1000

CANCER OF	JOACHIMSTHAL MINERS		VIENNA, MALES 15-79 YEARS OLD
	(a) 1929-1938	(b) 1929-1930 and 1933-1938	1932-1936
Lung	9.77 ± 1.53	8.28 ± 1.56	0.34 ± 0.01
Larynx	0.23 ± 0.23	0.29	0.07
Skin	0.23	0.29	0.05
Other organs	0.67 ± 0.39	0.31 ± 0.30	1.98 ± 0.02
All organs	10.90 ± 1.59	9.17 ± 1.55	2.44 ± 0.03

From Table 6 it is evident that the higher total rate for Joachimsthal is chiefly due to the enormous rise in frequency of lung cancer. There is also an increase in the larynx and skin cancer rates. Since both these sites are exposed to irritation by the radioactive dust, it is open to question whether this increase is only by chance. The lack of tumors in "other organs" is statistically significant.

Taking the age specific death rates of a city like Vienna, and knowing the number and the age of the deceased miners and pensioners, one can estimate the number of men expected in each group under normal conditions. This is done in Table 7.

During the time under consideration, the actual number of person-years was about 4300 (including 860 observed years of pensioners) whereas according to the calculation of Table 7 one would have expected 47,031 person-years. In the age groups 35-44 and 45-54 the number of actual person-years is only a small percentage of the figures calculated in the table. Thus the cancer mortality of these two age groups is highly increased, especially in the group 35-44 (perhaps more than twenty times). As far as the deaths indicate, there are pensioners in

TABLE 7

Miners and pensioners in Joachimsthal, 1929-1938. Actual and expected person-years at risk on the basis of the number of cancer deaths

AGE (*years*)	(a) MINERS AND PENSIONERS	(b) VIENNA, MALE POPULATION	(c) PERSON-YEARS OF MINERS	
	Actual number of cancer deaths	Cancer mortality per 1000	Expected according to (b)	Actual
15-29	..	0.074	...	?
30-34	1	0.134	746	?
35-44	18	0.516	34,882	?
45-54	21	2.037	10,308	?
55-64	6	5.960	1,040	?
65-74	..	13.280	...	?
75-79	1	18.181	55	?
	47	2,440	47,031	4,300

all age groups above 35, but the bulk of them are over 55 years old. Therefore, the figures calculated in the table indicate a slightly increased cancer mortality in the age period 55-64, and a rather decreased cancer mortality in the older age periods.

The increased death risk of the Joachimsthal miners who are younger than 45 is not limited to cancer. According to the Austrian life table (1930-1933)[11], the actual non-cancer deaths which occurred at the age of 30-44 years correspond to 5175 person-years at risk. This is more than the actual total number of person-years at risk for all age-groups together. On the other hand, according to the actual non-cancer deaths for all age groups over 50, the number of person-years estimated (107) is very small. Miners and pensioners over 50 have a low mortality from non-cancerous diseases. In the age above 54 years there were altogether 13 deaths from all diseases. This figure corresponds to 299 person-years. The actual number was, in all probability, higher. Therefore the conclusion seems justified that for miners past the critical age 30-54 years the total mortality was lower than that of an average population.

[11] The chance of dying within one year per thousand men (1000 q_x) was at the age of 30 years 4.38, at the age of 35 years 5.62, and at 45 years of age 7.03.

4. DISCUSSION

The special conditions in the mines of Joachimsthal is the reason for my investigation. Such a high percentage of cancer in *one* organ as in the miners of Joachimsthal is known in experimental work, where it is brought about by breeding and selection. In human pathology, there are only a few examples in which about 90 percent of all tumors are concentrated in one organ. One example relates to the miners in Schneeberg; the other to the workers in Witwatersrand Gold Mines in South Africa. According to the report of the Miner's Phthisis Medical Bureau and to the Publications of the South African Institute for Medical Research, during 1925-1933, on the average 204,000 Bantu Negroes were employed in the Rand mines. In the 9 years out of 270 gold mine workers who died of cancer, 229 (85 percent) had a primary tumor in the liver (Berman). In these miners primary cancer of the skin, lip, oesophagus or stomach and second primary tumors in other organs than the liver were completely lacking.[12]

Such a proportion as 85 percent liver tumors is not a hereditary peculiarity for the Bantu Negroes. Hospital statistics for males in South Africa show liver proportions of 22.5 to 25 percent (Berman, McVivar). In hospitals of Portuguese Africa 28.7 percent of all malignancies are liver cancers (des Ligneris). This indicates about 40 percent liver cancer for males. In the United States, Negroes have a higher proportion of liver tumors than the white people (R. Pearl and A. L. Bacon), but a much lower one than that in Africa.

TABLE 8

Primary malignancies according to race, sex, and organ in a necropsied population of Baltimore (Pearl and Bacon)

	WHITE		NEGRO	
	♂	♀	♂	♀
Liver	6	2	5	..
Bile ducts and gall bladder	6	21	1	2
All other organs	402	211	83	77
Totals	414	234	89	79

[12] The medical supervision and hospital facilities are very good there. Post-mortem examinations were made in 66 percent of the deaths.

In spite of the fact that the Bantu laborers spent but short working periods in the mines[13], the proportion of 85 percent liver cancer may represent a response to some peculiar and quite unknown carcinogenic condition in the gold mines. Similarly the 90 percent of lung cancer in Schneeberg or Joachimsthal is statistically associated with work in those mines, and may be due to such work, even if the statistical association does not prove a causal connection.

In our previous studies there have been shown many examples where the increase of cancer frequency in an additionally irritated organ was either partially or even completely compensated for by a decrease of cancer frequency in other organs. In the miners of Joachimsthal or Schneeberg such an equilibrium of the cancer mortality could never be achieved, as the number of additional lung cancer cases is several times higher than the total cancer frequency of a population taken at random as is shown in Table 6 *supra*.

As in my previous studies, we have to consider two questions: (1) whether the incidence figures in Table 6 do not disprove the theory of organ disposition as a decisive factor in the incidence of human cancer and in the organ distribution of the tumors; and (2) what factors account for the lack of cancers in the organs not exposed to the additional irritations.

According to cancer mortality rates in an average population, during the period 1929-1938 less than 10.5 miners and pensioners would have to die of cancer of all sites; actually, there were 47 cancer deaths in this period. Less than 1.5 lung cancer deaths were to be expected; actually, forty-two miners and pensioners succumbed to lung cancer. There were also to be expected 8.7 fatal non-respiratory cancer cases; there were, however, only four, two of these being the dubious stomach cases already noted. Taking these details into account, one may divide the 42 lung cancer victims into the three following groups: (1) men who might have contracted a lung cancer even if they had never worked in the mines; (2) men who normally without having worked in the mines might have produced cancer in other than the respiratory organs (11.4 ± 4.9 percent of all lung cancer cases belong to this group); and (3) men who without working in the mines might have lived longer than they did, and might never have died of cancer. This third group

[13] Twenty-three percent less than one year, 27 percent over one to two years, 20 percent over two to three years, 13 percent over three to four years, 7 percent over four to five years, and 10 percent longer than five years.

appears to represent about 85 percent of all lung cancer cases. It suggests that the active factor, most probably the radioactivity, is really carcinocreative. It further suggests that the incidence of cancer depends much less, if at all, on an inherited organ disposition, than on extrinsic factors.

The question of what factor accounts for the lack of cancers in the non-respiratory organs of the miners is more difficult. It is possible that the potential carriers of these tumors were killed by the lung cancer at an earlier age. If this explanation holds, then one understands the complete lack of second primary tumors in the non-respiratory organs of the 28 post-mortem-examined lung cancer cases. However, this explanation may be wrong. From previous work we have to bear in mind that in the United States Navy the additional cancers in the more exposed and irritated organ (skin) appear also at an earlier age. Yet, in spite of their being non-fatal, a large group of internal cancers which should be expected at a certain age do not appear. The problem of second primary tumors needs further study before any answer concerning their expected and actual incidence can be given.

Finally it is to be emphasized that the whole Joachimsthal experience is still statistically small, and therefore any generalizations must be viewed with great caution and reserve.

5. SUMMARY AND CONCLUSIONS

1. The miners in Joachimsthal have a high percentage of malignancies (53 percent) among their deaths; a several times increased cancer mortality rate due to an enormous frequency of pulmonary cancers in the age period 35-54; an exceptionally high proportion of primary lung cancers; a reduced incidence of cancer in non-respiratory organs; an increased mortality from causes other than cancer in the younger age groups.

2. The miners in Joachimsthal have an increased incidence of multiple primary tumors in the lungs, but a complete lack of second primary tumors in other organs.

3. The active factor in the radium mines presumably increases the number of men who suffer from cancer by increasing the tumor susceptibility of the younger and middle age groups almost to the level of the higher ages, and presumably changes the organ distribution of the primary tumors. Thus this factor may be regarded as displaying carcinoprovocative, as well as carcinocreative activities.

4. The cancer frequency and mortality in a population is changeable to a high degree by additional carcinocreative factors; yet it is less changeable than the organ distribution of the primary tumors. The age distribution of cancer cases depends to a high degree on extrinsic factors.

5. Systematic investigations in other mines would be of great value in the study of human cancer.

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NOTES

RECORDS OF TOTAL REPRODUCTION[1]

SUCH knowledge as can at present be derived from official vital statistics about human fertility, and reproductivity generally, has its source in birth certificates from which natality statistics are compiled. From the viewpoint of theoretical biology this is not an entirely adequate or satisfactory source, nor does it, indeed, altogether meet the needs of practical demography. For birth certificates, in the first place, relate only to overtly fertile women. They furnish no direct information whatsoever about the important phenomenon of sterility, or childlessness from whatever cause. No birth certificate is ever filled out for a sterile or a childless woman. In the second place birth certificates can accurately record the phenomena of realized fertility at the moment of realization only, from the nature of the case biologically. No birth certificate can positively certify that the birth thereon is the last one the surviving, unsterilized mother is ever going to have. So it results that from official natality statistics it is impossible to get information that is precise about completed fertility (total reproduction accomplished by the individual). Resort must be had to devious and sometimes dubious physiological inferences from chronological age in order to reach an approximation to total fertility figures, utilizing the information on the birth certificate as to the number of births produced by the mother prior to the one for which the certificate is made out.

For these and other reasons that need not be here detailed, students of human fertility find themselves considerably hampered, in their efforts towards more penetrating analysis of the problem, by the limitations to the useful information that can be got from birth certificates and

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their derivative official statistics. The purpose of this note is to suggest that if the officials who collect vital statistics, national, state, county, and city would alter their procedure in one single small particular, the means would at once be at hand to increase greatly our understanding of human fertility and the factors that influence it. The suggestion is that birth and stillbirth certificates be left just as they are now, but that one more item be added to the standard *death certificate* as it now exists. That item would be embodied in the question:

How many children did the deceased ever produce?

It is not important in the present connection to quibble over the matter of precisely how this question should be worded on the standard *death* certificate. The essential thing here is to emphasize that the point in the life history of an individual at which it can be asserted with a maximum of assurance that reproductivity is at an end, and the fertility record is completed, is when that individual is dead.

If such an item were routinely filled on all death certificates a number of great advantages would at once accrue. First of all it would be possible to tell, as by a count, the number of married women past the menopause who never reproduced at all, a figure now unknown and only more or less approximately guessed. Secondly if, for a given year, the mean total reproductivity of a group of women *dying* at age 40, to take a single age as an example, were to be analytically compared with the mean number of children ever born (compiled from the birth certificates) to women *living* at age 40 and bearing a child that year, we should be farther ahead than ever before in evaluating the extent or severity of natural selection now acting on mankind.

It is not necessary to weary students of population problems with a list of other advantages that would accrue, or of interesting problems that at last could be attacked. Everyone will think of them. Naturally if the plan were adopted the registration of completed fertility (for that is what it means) would not be perfect at the start. But presumably it would improve as physicians and registrars got familiar with the idea, just as all other registration of vital statistics has improved with the passage of time and the efforts of people to make it better. And perhaps after completed fertility registration got going well it might be possible to expand the question on the death certificate just a little, into a table like this:

Write in this column the calendar year in which the deceased was married, and if married more than once, the year in which each successive marriage was contracted.	Write in this column the number of children produced from each of the marriages started on the dates indicated in the preceding column.
1. 2. 3. etc.	

When everyone got accustomed to putting *this* information regularly on every death certificate, then indeed the population student's millenium would have been ushered in.

RAYMOND PEARL

FIFTH INTERNATIONAL CONGRESS FOR THE UNITY OF SCIENCE

THE FIFTH International Congress for the Unity of Science is to be he held at Harvard University, September 5-10, 1939.

The theme of the Congress is *Logic of Science*: interest will center upon the relation of concepts, laws, and methods of the various sciences. Attention will be devoted to general problems connected with the unification of science, the relation of the physical and biological sciences, the logic of the physical sciences, and the relation of the biological and the socio-humanistic sciences. There will also be a number of special sessions and symposia concerned with special problems and fields. Professor P. W. Bridgman is the Chairman, and Dr. W. V. Quine is Secretary, of the Committee on Arrangements at Harvard University. The Congress is sponsored by the International Committee of the Congresses for the Unity of Science, the International Institute for the Unity of Science, and, in America, the American Association

for the Advancement of Science, the Philosophy of Science Association, the Association for Symbolic Logic, and the American Philosophical Association.

Those requesting later notices of the Congress are asked to send their names and addresses to Professor Charles W. Morris, University of Chicago, Chicago, Illinois.

RECENT LITERATURE

USEFUL IN THE STUDY OF HUMAN BIOLOGY

In this department will be noticed the books and reprints which are currently received at the Editorial Office. Publications intended for notice here should be addressed to Dr. Raymond Pearl, Department of Biology, School of Hygiene and Public Health, 1901 East Madison Street, Baltimore, Maryland, U. S. A.

I. EVOLUTION AND GENETICS

1. *Evolution — General Principles*

BRADLEY, JOHN H. Patterns of Survival. An Anatomy of Life. *New York* (The Macmillan Co.), 1938. Pp. 223. 8⅜ × 5¼ inches. $2.25.

CHANEY, RALPH W., MAXIM K. ELIAS, ERLING DORF, DANIEL I. AXELROD, and CARLTON CONDIT. Miocene and Pliocene Floras of Western North America. *Contributions to Palaeontology, Carnegie Institution of Washington Publication* No. 476. *Washington, D. C.*, 1938. Pp. 272 + 27 plates. 10 × 6¾ inches. $3.00 (paper); $4.00 (cloth). [Bibliographic footnotes.]

GATES, R. RUGGLES. The species concept in the light of cytology and genetics. *American Naturalist*, Vol. 72, pp. 340-349, 1938. [Bibliography of 20 titles.]

KUHN, OSKAR. Die Phylogenie der Wirbeltiere auf Paläontologischer Grundlage. *Jena* (Gustav Fischer), 1938. Pp. viii + 94. 9½ × 6½ inches. RM. 4.50 (paper). [Bibliographic footnotes.]

LAUFER, BERTHOLD. The American Plant Migration. Part I: The Potato. Prepared for Publication by C. Martin Wilbur. *Anthropological Series, Field Museum of Natural History*, Volume 28, Number 1, July 28, 1938. Publication 418. *Chicago*, 1938. Pp. 132. 9½ × 6 inches. $1.50 (paper). [Bibliography of 13 pages.]

LICHTIG, IGNAZ. Die Entstehung des Lebens durch stetige Schöpfung. *Amsterdam* (N. V. Noord-Hollandsche Uitgevers Mij), 1938. Pp. xx + 371. 10½ × 7¼ inches. H. gulden 6. (paper); H. gulden 7.50 (cloth). [Bibliography of 235 titles.]

LILLIE, RALPH S. The nature of organizing action. *American Naturalist*, Vol. 72, pp. 389-415, 1938.

MCKEE, EDWIN D. The Environment and History of the Toroweap and Kaibab Formations of Northern Arizona and Southern Utah. *Carnegie Institution of Washington Publication* No. 492. *Washington, D.C.*, 1938. Pp. viii + 268 + 48 plates. 10 × 6¾ inches. $3.00 (paper); $4.00 (cloth). [Bibliographic footnotes.]

STURTEVANT, A. H. Essays on evolution. II. On the effects of selection on social insects. *Quarterly Review of Biology*, Vol. 13, pp. 74-76, 1938. [Bibliography of 5 titles.]

STURTEVANT, A. H. Essays on evolution. III. On the origin of interspecific sterility. *Quarterly Review of Biology*, Vol. 13, pp. 333-335, 1938. [Bibliography of 8 titles.]

WILSON, ROBERT W., JOHN R. SCHULTZ, HILDEGARDE HOWARD, EDWIN H. COLBERT, J. D. LAUDERMILK, and P. A. MUNZ. Studies on Cenozoic Vertebrates of Western North America. *Contributions to Palaeontology, Carnegie Institution of Washington Publication* No. 487. *Washington, D.C.*, 1938. Pp. 281 + 48 plates. 10 × 6¾ inches. $4.00 (paper); $4.50 (cloth). [Bibliography of 1½ pages.]

2. *Human Evolution*

BASCHMAKOFF, ALEXANDRE. Cinquante Siècles d'Évolution Ethnique autour de la Mer Noire. Études d'Ethnographie, de Sociologie et d'Ethnologie. *Tome* I. Paris (Paul Geuthner), 1937. Pp. x + 177 + [3] + 2 plates. 9¼ × 6⅜ inches. 40 francs (paper). [Bibliographic footnotes.]

DREYER, T. F. The fissuration of the frontal endocranial cast of the Florisbad skull compared with that of the Rhodesian skull. *Zeitschrift für Rassenkunde*, Bd. 8, pp. 192-198, 1938. [Bibliography of 11 titles.]

GREGORY, WILLIAM K., MILO HELLMAN, and G. EDWARD LEWIS. Fossil Anthropoids of the Yale-Cambridge India Expedition of 1935. *Carnegie Institution of Washington, Publication* No. 495. *Washington, D.C.*, 1938. Pp. 27 + [1] + 8 plates. 10 × 6¾ inches. $1.00 (paper); $1.25 (cloth). [Bibliography of 2 pages.]

WEIDENREICH, FRANZ. Reconstruction of the entire skull of an adult female individual of *Sinanthropus pekinensis*. *Nature*, Vol. 140, p. 1010, 1937. [2 bibliographic footnotes.]

WEIDENREICH, FRANZ. The relation of *Sinanthropus pekinensis* to *Pithecanthropus*, *Javanthropus* and Rhodesian Man. *Journal of the Royal Anthropological Institute*, Vol. 67, pp. 51-65 + 4 plates, 1937. [Bibliography of 14 titles.]

WEIDENREICH, FRANZ. Discovery of the femur and the humerus of *Sinanthropus pekinensis*. *Nature*, Vol. 141, pp. 614-617, 1938.

WEIDENREICH, FRANZ. The ramification of the middle meningeal artery in fossil hominids and its bearing upon phylogenetic problems. *Palæontologia Sinica*, New Series D, No. 3; Whole Series No. 110, 1938. Pp. 16 + 6 plates. [Bibliography of 21 titles.]

3. *Prehistory and Archaeology*

BERGSØE, PAUL. The Gilding Process and the Metallurgy of Copper and Lead among the Pre-Columbian Indians. Translated from Danish by C. F. Reynolds. *Ingeniørvidenskabelige Skrifter* Nr. A 46. *Copenhagen* (Danmarks Naturvidenskabelige Samfund), 1938. Pp. 58 + 5 plates. 9¾ × 6¼ inches. 2 Kroner (paper). [Bibliography of 32 titles.]

HARGRAVE, LYNDON L. Results of a study of the Cohonina branch of the Patayan culture in 1938. *Museum Notes* (*Museum of Northern Arizona*), Vol. 11, pp. 43-50, 1938. [Bibliography of 11 titles.]

JACKSON, A. T. Picture-Writing of Texas Indians. *University of Texas Publication* No. 3809, March 1, 1938. (*Anthropological Papers*, Vol. II. *Bureau of Research in the Social Sciences Study* No. 27. *Austin, Texas*, 1938.) Pp. xxv + 490. 10⅛ × 6¾ inches. Free. [Bibliography of 5½ pages.]

DE PRADENNE, VAYSON. La Préhistoire. *Paris* (Armand Colin), 1938. Pp. 224. 6¾ × 4½ inches. 15 francs (paper); 17.50 francs (cloth). [Bibliography of 1 page.]

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WAUCHOPE, ROBERT. Modern Maya Houses. A Study of Their Archaeological Significance. *Carnegie Institution of Washington Publication* No. 502. *Washington, D.C.*, 1938. Pp. vii + 181 + 37 plates. 11½ × 9 inches. $3.00 (paper); $3.50 (cloth). [Bibliography of 2½ pages and bibliographic footnotes.]

WEBB, WILLIAM S. An Archaeological Survey of the Norris Basin in Eastern Tennessee. *Smithsonian Institution, Bureau of American Ethnology Bulletin* 118. *Washington* (Government Printing Office), 1938. Pp. xv + 398 + 152 plates. 9⅛ × 5⅝ inches. $1.00 (paper). [Bibliography of 3½ pages and bibliographic footnotes.]

4. *Genetics — General Principles*

CASTLE, W. E. Sex and genes. *Scientific Monthly*, Vol. 46, pp. 344-350, 1938.

SHULL, A. FRANKLIN. Adaptation in the light of genetics. *Current Science*, Special Number, March, 1938, pp. 31-33.

STURTEVANT, A. H., and K. MATHER. The interrelations of inversions, heterosis and recombination. *American Naturalist*, Vol. 72, pp. 447-452, 1938. [Bibliography of 8 titles.]

5. *Human Heredity*

FRETS, G. P. The heredity of rare nervous diseases. *Eugenical News*, Vol. 23, pp. 41-44, 1938. [3 bibliographic footnotes.]

GATES, R. RUGGLES. Blue eyes in natives of Ceylon. *British Medical Journal*, Vol. 1 for 1938, pp. 921-922. [1 bibliographic footnote.]

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6. *Eugenics*

LENNOX, WILLIAM G. Should they live? *American Scholar*, Vol. 7, pp. 454-466, 1938. [9 bibliographic footnotes.]

II. GROUP BIOLOGY

1. *Environment of Man*

AUSTRALIA, COMMONWEALTH OF. Final Report of the Advisory Council on Nutrition. Together with Appendices. *Australia*, 1938. Pp. viii + 166. 13⅜ × 8¼ inches.

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2. *Public Health and Hygiene*

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3. *Migration*

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4. *Population*

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5. *Mortality and General Vital Statistics*

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6. *Morbidity and Epidemiology*

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